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DEPARTMENT OF ENERGY'S SUPERCONDUCTING SUPER COLLIDER PROJECT

HEARING

BEFORE THE

SUBCOMMITTEE ON
ENERGY RESEARCH AND DEVELOPMENT

OF THE

COMMITTEE ON
ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

ONE HUNDRED SECOND CONGRESS

FIRST SESSION

ON THE

DEPARTMENT OF ENERGY'S SUPERCONDUCTING SUPER COLLIDER PROJECT

APRIL 16, 1991

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DEPARTMENT OF ENERGY'S SUPERCONDUCTING SUPER COLLIDER PROJECT

TUESDAY, APRIL 16, 1991

U.S. SENATE,
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The subcommittee met, pursuant to notice, at 2 p.m., in room SD-366, Dirksen Senate Office Building, Hon. Wendell H. Ford, presiding.

OPENING STATEMENT OF HON. WENDELL H. FORD, U.S. SENATOR FROM KENTUCKY

Senator FORD. I see Secretary Moore is here. He has been here all day. He might as well just pitch a tent here the way the energy bill is going.

Good afternoon, ladies and gentlemen.

Today, the Subcommittee on Energy Research and Development is holding a hearing on the Superconducting Supercollider, the SSC. The SSC will be the largest science project ever built. It is a 54-mile long—it started out at 50 miles and it is getting longer—high-energy physics particle accelerator. It will cost over $8 billion. And some say it now might go to $11 billion. It started out at $3.8 billion. And so we are moving up. Its purpose is to answer the most basic questions: what is the universe made of and what forces hold it together?

Every year the SSC demands more and more money. The Department of Energy's budget request for this year is $533 million. That is twice the amount the Department received last year. It is 20 percent of the Department's total science budget for the year.

The budget request for the SSC will continue to grow when construction is in full swing in 2 years. The SSC will demand over $1 billion annually. The Department says the SSC will be built with new money. They tell us it will not be at the expense of other science programs.

Yet, last year's budget agreement does not allow for new money. Everything we do now is pay as you go. So it is clear that other programs will help pay for this project. There is no other way, in my opinion, to do it. Other projects will be affected, but we do not know which ones or to what degree.

I am afraid we do not know yet the extent of the Federal Government's liability. 3 years ago the Department said the SSC would be built for $6 billion or it would not be built.

Today the Department says the SSC will cost a little over $8 billion. One other estimate has placed the cost as high as $11 billion.

I simply do not know where we will get this money. One-third of the money is to come from non-Federal sources. That is almost $2.6 billion. $1 billion has come from the State of Texas. But the Department has not found the other $1.6 billion.

I am worried that half-way into the project we will run into a glitch: a technical problem will delay the project. Or in 1 year Congress will not fully fund the Department's request. Or the non-Federal contributions will not come through.

The Department tells us that for every year the project is delayed, the cost increases by $400 million. At that rate, we could not possibly find the money for the SSC.

But there are many other unknowns that could cause just such a delay. One thing seems certain to me. We do not know yet how much we will pay for the SSC.

As you can see, I have a number of concerns, gentlemen, about the SSC. And I hope that you will be able to address them today.

We have excellent witnesses, and I look forward to their testimony. These are experts, and their testimony will be very, very important.

[The prepared statements of Senators Johnston and Domenici follow:]

PREPARED STATEMENT OF HON. J. BENNETT JOHNSTON, U.S. SENATOR FROM LOUISIANA

I want to thank Senator Ford for holding this hearing on the Superconducting Super Collider. This is an important hearing. I appreciate Senator Ford's effort, especially when we are so busy.

I approach the subject of high-energy physics with a great deal of fascination and curiosity. It is the most basic research of any kind that this country does. It inquires into the very nature of matter and energy. It tries to answer the most basic of all questions—how does the universe operate at the fundamental level?

These kinds of inquiries require particle accelerators. Accelerators are to particle physics what telescopes are to astronomy, or microscopes to biology. All these instruments reveal and illuminate worlds that would otherwise remain hidden from our view. The SSC will be the largest and most sophisticated scientific instrument in the world. It is also the next logical step in particle accelerators.

I believe that the SSC is an important project. My commitment to keeping the United States at the edge of science and technology is unwavering. I also have a number of concerns.

My concerns lie in three general areas: cost and certainty of design, science priorities, and U.S. technological competitiveness. Let me say a couple of things about each of these.

Over the past two years, the cost estimate for the SSC has increased considerably. That increase can be largely attributed to design changes. The Department says it is now comfortable with its cost estimate of $8 billion. I hope that means we also have certainty of design. I hope we will not be faced over and over again with further design changes and resultant cost increases.

If there is still uncertainty either in design or in our ability to get foreign contributions to offset the total costs, we need to know that now. I would rather see the Department say that there is still uncertainty then to once again commit themselves to a figure and schedule set in stone.

I am also concerned about how we determine what our science priorities should be. One problem with the science budget in this country is that we have no science budget. We have no one committee or Department looking at science as a whole. There is no way to compare one science project against another—to decide this project is more worthy than that project.

Finally, I want to once again emphasize a point I brought up last year. I am very concerned about how much of the SSC technology we will be giving away. In order

to obtain foreign contributions to the SSC I hope we will not have to give away the rights to this important technology.

Our past investment in particle accelerators has resulted in advances in microcircuits, lasers, medical treatments and the understanding of disease. Medical tools like cat scans owe their origin to accelerator technology.

The new technologies the SSC may bring forth are unknown as yet. But I would hate to see them be given away right from the beginning.

I look forward to hearing from our distinguished witnesses on all of these important issues.

PREPARED STATEMENT OF HON. PETE V. DOMENICI, U.S. SENATOR FROM NEW MEXICO

Today we examine the status of one of this country's most exciting scientific endeavors. There is no dispute within the scientific community that the Superconducting Super Collider carries with it the promise of the discovery of the origins of our universe, an astounding possibility by anyone's standards. However, this project also carries with it the heavy burden of high costs in the face of fiscal restraint and concomitant concerns that this megaproject will force reductions in other areas of basic research.

No one in the Congress is more supportive than I of an increased national commitment to growth in science and technology. Maintaining our preeminence in this field is the foundation of our worth and leadership in the international community. Similarly, no one is more mindful than I of the number of meritorious scientific projects that are competing for limited federal dollars. We must ensure that we do not short-change research that may produce near-term practical applications as we continue our search for the secrets of our beginnings.

The Department recently released an updated cost estimate for the SSC that increases the final cost from $5.9 billion to $8.2 billion. Is this truly the last of such increases? Some in the scientific community are concerned that progress by the European community on an accelerator similar to the SSC may obviate the need for the latter.

Another issue that clouds the progress of this project is the amount and nature of foreign participation in its development. Is it wise to allow other countries to benefit from the development of technologies and industries which could otherwise be developed in this country? What is the appropriate involvement of foreign countries in the construction and operation of the facility if contributions are monetary rather than in kind?

All of these matters will be addressed by the witnesses today and I look forward to their testimony.

Senator FORD. Dr. Bromley, if you would like to proceed with your testimony, if you would highlight it. I do have a few questions for you and for Secretary Henson.

You may proceed.

STATEMENT OF DR. D. ALLAN BROMLEY, DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY, EXECUTIVE OFFICE OF THE PRESIDENT

Dr. BROMLEY. Thank you, Mr. Chairman.

I want to begin by thanking you for this opportunity to testify about the administration's proposal for the Superconducting Supercollider. With your permission, Mr. Chairman, what I would do is to present briefly some oral excerpts from my formal testimony and request that the formal testimony be included in the record.

Senator FORD. Without objection, your testimony will be included in the record.

Dr. BROMLEY. Thank you, Mr. Chairman.

I shall discuss very briefly some of the science expected from the SSC's research and development. But the SSC is only one component—albeit a very important one—of the R&D portfolio that we are proposing to you this year, and this portfolio ranges all the way

from major projects like the SSC to enhanced support for individual investigators in the Nation's universities. Finally, I would like to highlight some issues that I think are particularly germane to the SSC.

When it is completed, the SSC will be completely unique. It will be the world's preeminent facility for elementary particle physics research. I think we can be quite confident that it is going to provide profound and fundamental advances in our understanding of matter, the forces of nature, our universe, and our place in that universe.

Over the past 50 years, building on experimental results that have come from a whole generation of accelerator facilities, some of which are much smaller than the one we are talking about today, physicists—both experimental and theoretical in this country and around the world—have built a comprehensive picture of nature, a theory that is now known as the Standard Model. It is as close as we have come thus far to developing a theory of everything. It has been remarkably successful in reproducing experimental observations and in suggesting new and challenging measurements that are increasingly within our scope.

Despite this success, however, Mr. Chairman, some very fundamental questions remain. One of these is that the Standard Model has been demonstrated to fail at energies in excess of 1 TeV because the model predicts that the probability of two of the intermediate bosons interacting is greater than 100 percent. When a model does that, it tells you that we do not understand what we are doing.

The model also fails because it does not answer one of the most fundamental questions. That is, where does mass originate? How do particles acquire mass? There are various suggestions in the model. Perhaps there exists in nature something called a Higgs particle. If so, the interaction of the Higgs field with all the other particles of nature gives them mass. It would be a major discovery if we could find this fundamental Higgs particle. We certainly cannot do it without something that is as powerful and as great an advance as the SSC would represent.

The theory that we have, the Standard Model, really does not give us very much in the way of prediction. That is why it is important for us to have as high an energy as possible, because it would be a great pity to do this search and find that we were just short of the energy required to produce the particles that would be fundamental to our understanding of the universe.

That is only a single example. In my testimony, I have given a number of others. But the important thing that I would have to emphasize is that, as with any other frontier facility, Mr. Chairman, the surest prediction that I can make today is that I would not be able to even guess as to what the most important or most fundamental discoveries will be. This opens up a totally new frontier, and no one can really predict what will be found on that frontier.

Now, before I turn to the budget considerations, which are, of course, enormously important for the SSC, I would, with your permission, very quickly review the 1992 budget request. We have asked, on behalf of the President, for $75.6 billion for research and

development. That is an increase of 13 percent over the amount appropriated for fiscal year 1991. Within that amount, basic research—research for which it is impossible to predict when, where, or to whom the benefits will flow—would be increased by 8 percent over the 1991 levels. Funding for research and development facilities, which includes the SSC, would increase by 15 percent to $3.54 billion.

Basic research, despite its enormous importance, accounts for a relatively small fraction of the total R&D budget of the Federal Government. But it is an indispensable part of our research and development enterprise. It provides the fundamental concepts and discoveries that lead to new products, new processes, and qualitatively new understanding and developments.

In this Nation we are unique in the developed world in that our research is carried out in close synergism with our education at the higher levels. In the course of doing research, we therefore train the scientists and engineers who carry today's science and technology forward into the future.

The fiscal year 1992 budget proposes action in several Federal agencies that are designed to strengthen this basic research component of our overall R&D enterprise. We have been aware, sir, that over the past few years individual investigators in the Nation's universities and colleges have had growing difficulty finding support to follow up on the major opportunities that past success have created. These are opportunities that, if we can follow up on them, promise a major return to the taxpayer, a major improvement of our quality of life, and a major return on the investment that you, sir, and your colleagues in the Congress have made in supporting this research.

We, recognize however, that in recent years there have been growing problems both in terms of young investigators obtaining support and established investigators losing support, in many cases at the very peak of their productivity and creativity. To correct that situation, sir, we have requested substantial increases both in the National Science Foundation and in the National Institutes of Health. We have also targeted, in both of those agencies, substantial increases at the level of the individual investigator.

We have also proposed substantial increases for basic research in the Departments of Agriculture and the National Aeronautics and Space Administration. In the Department of Energy, where our attention focuses this afternoon, the budget calls for $1.76 billion for the conduct of basic research, biological, environmental and basic energy sciences, as well as nuclear and high-energy physics, where the Department of Energy carries a major responsibility.

In addition, the budget request includes a separate category of funding for research and development facilities. This incorporates the SSC project, $43 million to initiate construction of a new injector for the elementary particle physics facility at Fermilab, and $147 million for continued construction of several important advanced photon and neutron facilities for materials science research and for the Relativistic Heavy Ion Collider, a nuclear facility that is just beginning construction at the Brookhaven National Laboratory.

If I might summarize, then, we are investing our research and development dollars in a very broad range of activities, Mr. Chairman, from the construction of projects like the SSC to the funding of individual investigators doing research where their entire apparatus fits comfortably on the top of a small table.

Against this perspective on the overall proposed basic research budget, let me return to the SSC. We have requested $534 million, as you have noted, for the SSC in fiscal year 1992. I would emphasize that the administration has taken a very strong position from the very beginning—and it continues to be the administration's position—that funding requirements for construction of the SSC will not be allowed to adversely affect support for the conduct of forefront research by individual scientists, small groups, or users of other large facilities.

I am satisfied, sir, that we have achieved this goal in the proposed budget request for 1992. But I do not mean to imply that this was easy or that difficult choices could or would be avoided. The administration determined that large increases were needed for DOE research on global climate change and on high-performance computing, and concluded reluctantly that other increases, in areas involving some biological and environmental research in DOE, for example, could not be supported simultaneously.

An essential ingredient of the administration's plan to construct the SSC without cutting into other areas of research is that one-third of the construction costs should be born by non-Federal sources. The State of Texas has already contributed $1 billion of this total. The administration is working with the DOE to convince foreign governments to provide the balance of the non-Federal funding.

We need, sir, your help. I believe that a number of potential foreign partners—in fact, many have so indicated—are poised to join us in this effort, but they are waiting to see whether we in the United States have the will to proceed expeditiously. The most significant action that the Government could take to encourage foreign participation is to appropriate the $534 million required to keep this project on schedule. Any significant reduction, unhappily, will increase the overall cost and decrease the attractiveness of the project to prospective partners and will, I believe, substantially reduce the probability of our obtaining substantial international cost-sharing.

I would note also that the caps on discretionary spending in fiscal year 1993 and beyond that are mandated by the Omnibus Budget Reconciliation Act will make it next-to-impossible to compensate in future years for under-funding of the project in fiscal 1992. If we fail to provide the needed funds this year, we shall simply fall farther and father behind in the future. And, as we all know, construction costs will then escalate.

I would therefore urge you, Mr. Chairman, that together the administration and the Congress move forward now with this forefront facility.

I want to conclude by repeating what I said to you last year: the superconducting supercollider has enormous scientific merit. It will be critical to unraveling some of the most fundamental mysteries that we know in physical science. The origin of mass of the known

particles is one, along with the possibility of entirely new forces and a deeper understanding of what is currently wrong with our best models of the universe.

The SSC is a critical part of this administration's overall initiative in research and development to strengthen America's position as a world leader. We are committed to making this project a great success. We propose to do that, furthermore, while at the same time providing strong support for the research of individual scientists in this and other areas of science. We take that as a very important commitment.

That, sir, concludes my oral presentation.

[The prepared statement of Dr. Bromley follows:]

PREPARED STATEMENT OF DR. D. ALLAN BROMLEY, DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY, EXECUTIVE OFFICE OF THE PRESIDENT

Thank you for inviting me to testify concerning the Administration's proposals for funding to continue construction of the Superconducting Super Collider (SSC). The SSC will be the largest science project ever built. When completed, it will be the world's preeminent facility for elementary particle physics research and will remain so well into the next decade. It will reach energies of 40 trillion electron-volts (TeV), as compared with 16 TeV for the proposed Large Hadron Collider (LHC) at the European Center for Nuclear Research (CERN) and 2 TeV at Fermi National Accelerator Laboratory in Illinois. When it begins operation, it will provide profound and fundamental advances in our understanding of matter, of the forces of nature, of the universe, and of our place in it.

The SSC is the essential tool required for the next major step in unlocking the fundamental secrets of matter and energy. Building on over 50 years of accelerator-based research, physicists have developed a unified synthesis of the weak and electromagnetic forces—two of the four known fundamental forces in nature. The combination of this unified electroweak theory with the phenomena of the strong nuclear forces constitutes what is now called the Standard Model. It is no exaggeration to term this accomplishment an historic advance. The Standard Model has been remarkably successful in reproducing experimental observations and in suggesting new and challenging experiments, and no experimental results have yet been found that are not predicted within the framework of this theoretical model.

Nevertheless, fundamental questions remain. Among these are the nature of the vacuum and the origin of mass itself. In the Standard Model, it is assumed that the various particles of nature interact with an electrically neutral field—the Higgs field—which, if it exists, permeates the universe and assumes a nonzero background value even in a perfect vacuum. This symmetry-breaking interaction gives the particles an energy—and thus a mass—with respect to the vacuum. In the simplest form of the theory, the Higgs field would be represented physically by a single Higgs particle. In other versions, mass is imparted through interactions with a family of such particles. To date, however, no such particles have been observed using any existing particle accelerator.

The theory provides little precise guidance concerning the mass of the Higgs particle or particles, and thus it is essential to be able to search up to quite heavy masses, which requires high-energy beams. In fact, it is essential to be able to search up to masses (800 GeV/c^2) where the corresponding particle would decay so rapidly that its resonance width would become undetectably broad. The SSC design energy and luminosity will provide unique experimental access through this region. Failure to find the Higgs particle would imply new physics beyond the Standard Model—a most exciting possible result—which could then be probed in detail with the facility. In either eventuality, the SSC should provide definite clues to the fundamental mystery of symmetry breaking in the electroweak sector and to the related question of the origin of the masses of the known particles.

Moreover, there is already evidence for a fundamental failure internal to the Standard Model as the energies at which it is applied are increased. Present calculations using this model predict, for example, at energies above 1 TeV a probability greater than 100 percent of interaction of the heavy W particles, discovered at CERN, that mediate radioactive decay processes. But this is physically meaningless and is a signature for a missing component or major flaw in the theory. To probe this very interesting new region above 1 TeV with an adequate flux of particles to

obtain statistically meaningful results, it becomes essential to have an accelerator with the characteristics of the SSC.

These are only two examples of research that will be done with the SSC. It bears emphasis, however, that some of the most exciting physics to be done on the SSC is virtually impossible to foresee today. Construction of the SSC is a step into scientifically uncharted areas, and such a venture into the unknown can be guaranteed to produce rich and provocative results.

THE SSC IN THE CONTEXT OF THE FEDERAL R&D PORTFOLIO

Having briefly mentioned examples of the exciting and fundamental science to which the SSC will give access, I should like to provide an overall budget and policy perspective for the project. Throughout his first two years in office, President Bush has emphasized the importance of research and development as a long-term investment in the future of this nation, and the Fiscal Year 1992 budget fully reflects this commitment to science and technology. It proposes to allocate $75.6 billion for research and development, an increase of $8.4 billion, or 13 percent, over the amount appropriated for fiscal year 1991.

Increases for major categories of R&D support are equally substantial. Basic research would rise to $13.3 billion, an increase of $1 billion, or 8 percent, over 1991 levels. Applied research and development would go up 13 percent, to almost $60 billion. Funding for R&D facilities would rise 15 percent, to $3.54 billion.

In the first year under the Omnibus Budget Reconciliation Act—at a time when proposed expenditures above the level of inflation essentially have to be offset against other spending--this increase for research and development is a strong statement of the Administration's priorities. It testifies to the President's belief that we must continue to make the investments needed to ensure this country's leadership, economic strength, and security into the 21st century.

I have often said during this past year that the United States, as a nation, is underinvesting in research and development. This belief is widely shared in the Administration and, I believe, on Capital Hill. The increases proposed in our FY 1992 budget take important steps to address that underinvestment.

The President's Fiscal Year 1992 budget provides continued support for a broad range of federal R&D activities in areas such as basic research, energy, agriculture, defense, industrial technology, biotechnology, space, and health. This kind of ongoing and long-term investment over the past 45 years has given the United States the strongest science and technology enterprise that has ever existed. It is a testament to the public policy process in the United States—and ultimately to the American taxpayer and voters—that this country has been willing to make investments whose dividends we continue to reap. I trust that we will continue to make these investments.

In addition to ongoing R&D programs, this year's budget contains a number of new initiatives and areas of emphasis falling into six broad categories: basic research, technology development, defense research and development, space, global change, and education and human resources. Today, I shall outline only the initiatives in the basic research budget, to provide the perspective necessary for considering the SSC funding request.

THE SSC IN THE CONTEXT OF BASIC RESEARCH

Basic research accounts for only about 15 percent of the total amount spent on research and development in the United States. But basic research—and particularly the large fraction of that basic research carried out in universities and colleges—is an indispensable part of the nation's R&D enterprise. It provides the important fundamental discoveries and concepts that lead to new products and processes. It also results in the education of many of the highly trained scientists and engineers who will carry today's science and technology into the future. And it has a very high social rate of return through its effect on a wide variety of private sector activities. For example, Professor Edwin Mansfield of the University of Pennsylvania, a distinguished economist, has recently completed a detailed study that finds an average social rate of return on past investments in academic research of 28 percent.

Support for Individual Investigators

The federal government now supports more principal investigators at universities than ever before, reflecting real increases in the level of federal support for academic research. However, the number of such researchers competing for funds has increased even faster, which is largely a result of the emergence of exciting new scientific opportunities and of past successes in our training of high-quality doctoral-level

scientists and engineers. There has also been pressure to increase the size of such individual investigator grants—reflecting the increased complexity of science (sophistication inflation)—and to extend the duration of grants—to promote stability of support and to reduce the fraction of researchers' time and effort devoted to paperwork rather than research. Both of these changes create inevitable out-year mortgages. Such factors have caused the competition for available research funds at agencies such as the National Science Foundation and the National Institutes of Health to become so great that the situation has become a matter of serious concern in the research community.

Recognizing the many essential contributions of basic research, especially at universities, to our national future, the Fiscal Year 1992 budget proposes actions in several federal agencies designed to strengthen the individual and small group investigator component of the scientific enterprise.

At the National Science Foundation, the President has reiterated his commitment to double NSF's budget between 1988 and 1994. The budget proposes an 18 percent increase—over $400 million—for NSF, bringing it to a total of $2.72 billion. Support for the conduct of research, almost all of which is basic research in NSF, will increase by $284 million, or 16 percent, to a total of $2.1 billion. In addition, the budget proposes a crucial $50 million initiative to improve the research infrastructure by providing state-of-the-art instrumentation to university researchers. As with research funding, support for this instrumentation will be distributed on the basis of a competitive, merit-reviewed process. Federal support will be matched at least 50:50 by nonfederal funds.

Part of the effort at NSF to strengthen the general science and technology base involves specific programs. For example, interagency initiatives on global change and high performance computing and communications will be funded within NSF at a combined level of $333 million as part of the integrated national programs developed by the relevant FCCSET committees. In addition, $456 million of NSF's budget, 23 percent more than in FY 1991, will be directed to mathematics and science education as part of a new interagency initiative again coordinated by FCCSET.

To further strengthen the National Institutes of Health—the premier biomedical research establishment in the world—the President has proposed an increase of $334 million for basic research, or 7 percent, to a total of about $5 billion, with NIH funding to rise to $8.8 billion overall. This increase would allow for growth of about 9 percent in NIH's funding for research project grants awarded to individual investigators, providing for a broad base of fundamental advances.

Within the NIH total, $110 million is allocated to the Human Genome Program, with an additional $59 million in funding from the Department of Energy, resulting in an overall increase for the program of 26 percent. This program represents a coalescence and strengthening of the activity for many individual investigators who have been working on a wide variety of different genes. By focusing on the overall structure of human DNA and on determining the location and sequence of the estimated 100,000 human genes, the program will allow researchers to develop new diagnostic tests, new therapies, and new cures for a wide variety of human disease. Knowledge of the human genome and those of model systems will also be an invaluable resource throughout biomedical research and biotechnology.

Together, NSF and NIH support over half of the federally funded basic research done in the United States, and over 75 percent of the federally funded basic research done in universities. By focusing special attention on these agencies, the Administration plans to strengthen the individual investigator and small group research that remains the heart and backbone of American science and technology.

Basic Research in Other Civilian Agencies

Another important initiative is proposed for the Department of Agriculture. The National Research Initiative, which is a merit-based competitive research grants program open to investigators across the nation, is proposed to increase by 71 percent, to $125 million. This program will broaden the nation's science and technology base through research in such areas as food safety, water quality, global change, pest management, and farm income. The overall goals of the initiative are improvements in the quality and nutrition of food, a safer environment, more rational use of natural resources, and economically stabilized production systems.

In the National Aeronautics and Space Administration, basic research is slated to rise by $262 million—to a total of $1.96 billion—largely reflecting increases in space and environmental science. This year's budget makes a very strong commitment to the scientific components of the space program, in keeping with the report of the Advisory Committee on the Future of the U.S. Space Program (the Augustine report). It proposes $2.1 billion, an increase of 21 percent over FY 1991, for NASA's

space science programs, including astronomy, life sciences, planetary exploration, Earth science, and materials research. This represents about 20 percent of NASA's total budget, which is also in keeping with the Augustine Report. NASA's proposed budget includes support for the Earth Observing System (EOS), which is a vital component of the nation's overall integrated global change program and which, for the first time, will make simultaneous observations of the earth's surface by a whole suite of complementary instruments.

Finally, the proposed budget for the Department of Energy would provide $1.76 billion for the conduct of basic research into biological, environmental, and basic energy science and into nuclear and high energy physics. This amount, which does not include funding requested for scientific facility construction, is 2 percent above the previous year's appropriation. While this increase is small compared to those noted above for other agencies, I would remind you that the FY 1991 appropriation was 15 percent higher than that for FY 1990. The overall two-year growth provided for these programs is about what it should be, in my opinion.

In addition to DOE's budget allocation for the conduct of research, the request includes funding for R&D facilities. The facilities budget incorporates not only the SSC project, which is discussed below, but also $43 million to initiate construction of a new injector for the elementary particle physics facility at Fermilab as well as $147 million for continued construction of several important advanced photon and neutron facilities for materials science research and of the nuclear physics Relativistic Heavy Ion Collider at Brookhaven National Laboratory.

FUNDING FOR THE SSC

Against this perspective on the overall proposed FY 1992 basic civilian research budget, let me return to the SSC.

Funding for the Superconducting Super Collider is requested at $534 million for FY 1992, an increase of $291 million. I would emphasize that the Administration's position from the beginning has been, and continues to be, that funding requirements for construction of the SSC will not be allowed to adversely affect support for the conduct of forefront research by individual scientists, small groups, or the users of large facilities. I am satisfied that we have achieved this goal in the proposed FY 1992 budget request. I believe that the facts outlined above speak for themselves in this regard. But I do not mean to imply that it was easy or that difficult choices could—or will—be avoided. The Administration determined that large increases were essential for DOE research on global climate change and on high performance computing, and concluded reluctantly that other increases—in some other areas of biological and environmental research in DOE, for example—could not be supported simultaneously.

An essential ingredient of the Administration's plan to construct the SSC without cutting into other areas of research is that one-third of the construction costs of the SSC must be borne by non-Federal sources. The State of Texas has contributed a generous share—$1 billion—of this total, and DOE and the Administration have been working to convince foreign governments to provide the balance of nonfederal funding.

We need the help of the Congress. I believe that a number of potential foreign partners are poised to join us in this effort but are waiting to see if the United States has the will to proceed expeditiously. The most significant action that we can take to encourage foreign participation is to appropriate the $534 million that is required to keep the project on schedule. Any significant reduction will inevitably increase the cost—and decrease the attractiveness—of the project to prospective partners, and will, I believe, substantially reduce the probability of obtaining significant international cost sharing.

I should also note that the caps on discretionary spending in FY 1993 and beyond mandated by the Omnibus Budget Reconciliation Act will make it next to impossible to compensate, in future years, for any underfunding of the project in FY 1992. If we fail to provide the needed funds this year, we shall simply fall farther and farther behind in the future. The construction costs will then escalate correspondingly, and the rich scientific payoff that awaits us will be postponed into the next decade. I urge the Congress to move forward with this forefront facility.

I would like to conclude by repeating what I said to you last year. The Superconducting Super Collider has enormous scientific merit. It will be critical to unraveling the fundamental mystery of the origin of the masses of the known particles and holds promise of allowing us to track down the apparent flaws in our otherwise remarkably successful Standard Model. The SSC is a critical part of the Administration's initiative to strengthen America's position as a world leader in science and

technology. We in the Administration are committed to making this project a great success, and we propose to do so while assuring strong support for the research of individual scientists in this and other areas of science.

I shall be happy to answer your questions.

Senator FORD. Thank you very much, Dr. Bromley.

And the Chair would note the presence of Senator Craig, who has advised he has no opening statement. And therefore, we will proceed to Secretary Moore.

Secretary Moore.

STATEMENT OF W. HENSON MOORE, DEPUTY SECRETARY, DEPARTMENT OF ENERGY

Mr. MOORE. Thank you, Mr. Chairman. I would like to have my statement submitted for the record.

Senator FORD. Without objection it will be included in the record.

Mr. MOORE. Mr. Chairman, we agree with Dr. Bromley's testimony. We think the Super Collider is absolutely critical to the strengthening of the U.S. position as a world leader in science and technology. It is indeed an investment in our Nation's future. Basic science develops technology and technology develops, in turn, American jobs and prosperity.

The importance of the Super Collider is reflected in the size of the budget request for fiscal year 1992—$533.7 million. It was not done lightly. It took a great deal of effort and study within the administration to come forward with this kind of a project and this kind of a request. This request represents a significant ramp-up in Federal funding, as is usual in large construction projects. As you move from design stage to construction phase, you do have a ramp-up, and that is what we are now seeing for fiscal year 1992.

To meet the challenges imposed by such a large and complex project, we have taken several steps to institute strong management—stronger than the Department has ever had before, we believe, on any kind of a science project or any other kind of project. Before outlining that, I would like to comment, as Dr. Bromley did, on the contest which we think is a false one, between big science and little science. To us all science is important, big or little.

As Dr. Bromley pointed out, the SSC is not being built at the expense of other science. We see a 13 percent increase over the appropriations for fiscal year 1991 for total R&D Federal support, a 9 percent increase over fiscal year 1991 appropriations for basic research in the Federal budget, and a 15 percent increase over fiscal year 1991 appropriations for actual R&D facilities. As a matter of fact, over the last 5 years the Department of Energy's research budget and the National Science Foundation's research budget have increased by 50 percent. No science has been cut or is being cut for fiscal year 1992 to reach the funding levels necessary to get on with this project.

Moreover, the benefits we are seeing from the Super Collider benefit small science. As a matter of fact, out of the appropriations to the Super Collider, money is directly going to some 90 universities across the country as grants to do research work in support of this project. The State of Texas is contributing additional funds, so far just about matching those of the Federal Government, to those same and other universities.

The superconducting magnets alone represent a billion-dollar industry and are being used in hundreds of hospitals for magnetic resonance imaging. It is already beginning to have an effect in the technology of this country and in industry in this country. Other superconducting magnets may ultimately find use for energy storage in high speed trains—the Mag Lev.

Spinoffs of the SSC-related research will have applications outside the SSC in such industries as electronics, computing, energy, and communications. Particle accelerators, once used only for basic research to study the atom, are now being used by hospitals in hardening plastics to prevent breakdown and discoloration, thereby allowing reusable equipment in heart bypass operations. These new spinoffs are being used by American computer companies to make more powerful semiconductor chips, by hospitals to treat inoperable cancers, and by engineers to detect cracks in remote and inaccessible areas such as inside thick steel pipes and containers such as oil tankers.

Finally American industry will benefit in many areas: precision tool and process control, robotics, quality control techniques, instrumentation and diagnostics, improved superconducting material, cryogenics, control systems, precision power supplies and power conditioning, high-speed and low-cost specialized microprocesses, trained high technology employees. This is coming out of the actual design and preparation for the construction of the Super Collider.

Fiscal year 1992 is a critical year. It is our biggest ramp-up, as is usual in construction projects. Mr. Chairman, other nations are watching.

Turning now to the budget request itself for fiscal year 1992, the requested amount, along with $130 million from the State of Texas and an expected $20 million from foreign contributions in fiscal year 1992, represents a major commitment on the part of the Nation to this project. This increase in funding is critical in several ways to move forward with the SSC.

First, it allows us to maintain a cost-effective schedule with a funding profile that maintains cost and schedule. As Dr. Bromley said, less funding will mean delay and an increase in the total project cost. Secondly, it reflects the administration's strong support and commitment to a credible baseline, and that the project is on a sound technical and funding track. Thirdly, it demonstrates to potential partners that the Super Collider is moving ahead of schedule, that their participation is warranted and is now timely.

Strong support in fiscal year 1992 will bring the Super Collider to a state of maturity in design. The magnet performance will have been demonstrated in the accelerator system's string test in late fiscal year 1992. The accelerators for the injector will be in the final stages of design in fiscal year 1992. Geotechnical results will be in hand and firm estimates for tunnel construction will be available in fiscal year 1992, and large-scale detector concepts will be approved and beginning to be built in fiscal year 1992.

By the end of that fiscal year, key information on technical system performance, collider ring tunneling and detectors will be in hand to confirm the baseline cost and the schedule estimate. Fiscal year 1993 will initiate the major tunneling activities and ini-

tial phases of the actual magnet production, based on the progress in fiscal year 1992.

This path for the Super Collider project is predicated on very significant progress and accomplishments over the past 2 years. We have now instituted very strong management. We have established that. I have asked our two key managers to be here today so that the chairman may see them, and they will be available to visit with you, members of the committee or your staff, this afternoon, and will come back for other visits if that is recommended. First is Mr. Ed Siskin. Mr. Siskin, will you please stand? He has 27 years' experience in the private sector and is an accomplished engineer in building big projects. He is now the General Manager of the SSC laboratory.

Senator FORD. From looking at him, nobody would talk back to him.

[Laughter.]

Mr. MOORE. That is the whole idea. That is exactly the effect he is having. Thanks, Ed.

Also present is Joe Cipriano, who represents the Department of Energy and the Government. Likewise, he also carries a little weight with him.

[Laughter.]

Senator FORD. One of those was supposed to be out front.

Mr. MOORE. Mr. Chairman, we do not mess around. When you need two big tackles up front to open the way, that is exactly what we have gotten—two big tackles to do it.

Senator FORD. The difference between those two and me is I run faster.

[Laughter.]

Mr. MOORE. Mr. Cipriano we enticed from another Department of the Government. He has received awards many times as the Government project manager on numerous, big, technical projects. We believe we have two of the finest projects managers, one working for our contractor, Mr. Siskin, and the other working for the taxpayers, Mr. Cipriano. The two of them together have already instituted amazing progress in the several months they have been on the job running this project.

Texas is strongly supporting the SSC with land and funding. They have done everything we have asked them to do, and they are right on schedule with their contributions.

The accomplishments just recently under this management team include the architect/engineer/construction management contract being awarded to a world class builder, Parsons-Brinkerhoff/Morrison-Knudsen, on schedule and within the baseline budget.

General Dynamics and Westinghouse contracts have been negotiated as the leader and follower for the superconducting magnet industrialization program, on schedule and we believe they are going to come in within the budget. The SSC footprint has been approved and the land acquisition begun by the State of Texas. The land is being bought and turned over to the Federal Government ahead of schedule. Construction has begun on a magnet development laboratory, and a Record of Decision signed for construction and operation ahead of schedule and within budget. Successful 50 millime-

ter design exceeding performance requirements in all cases for the magnets has been determined, on schedule within budget.

Two large general purpose detector collaborations have been identified for the conduct of experiments. One for certain is on schedule and within budget. And the other one will be or it will be disapproved.

Solid build-to-cost baselines have been established for the project in January 1991. This is the report, Mr. Chairman, that was sent to you and the committee. We think that is the first time the Department has ever done this. The report relates to the entire history of the project and lay out how we got to where we are and how we intend to build to that baseline. In talking about that, it maintains the scientific objectives of the SSC specific to the Texas site with improved design. It has a more conservative design with validation of many of the cost elements. It establishes a firm basis for proceeding with the project. The Department and the Laboratory are committed to building to this baseline, reporting to the Congress on our progress to this baseline, and you holding us accountable to this baseline.

The total project cost of $8.249 billion represents approximately a $2 billion increase over the first estimate of the building of this project of $5.9 billion. There have been three cost estimates: in 1986, 1990, and the one we came through with in 1991. As you come down the curve of getting closer to knowing what you are doing with the project, as is true with any major research project, you come to the point you have a solid baseline and you are ready to build to that and that is where we are now.

These cost changes from 1986 to 1991 were not cost overruns but were due to design changes—about a half of that increase is attributed to schedule extensions and a less aggressive funding profile, recognizing the budget constraints of the Congress—about a quarter of the increase is because of contingency increases and revised estimates for updated escalation rates. We did fail to get full funding in fiscal year 1989, which cost us about a half billion dollar increase.

This baseline differs from the ICE estimates, the one you referred to in your opening statement, Mr. Chairman, of $11.8 billion, largely due to the management approach and judgments on technical costs and schedule risk. $1.2 billion is schedule risk and contingency of their report, $1.2 billion construction costs, and escalation in prior year costs, and $1.2 billion detector estimates. For the detectors, the $910 million cost envelope has been validated. We can build two large, general purpose detectors with the expected foreign participation that is normal in such matters as this for that amount of money.

The Super Collider is being built under strong management that is already having an impact on the budget and the schedule. We will have a report for this Congress in the next several weeks of all of the money spent to date, as of the end of fiscal year 1990, and so far in fiscal year 1991. We know we are on schedule and we believe we are under the budget, as prescribed in this document. But that report will be coming to you in about 2 weeks to give you that definitive information.

All major project activities are on or ahead of the baseline schedule, and we expect to stay that way with these competent managers we now have on board. The remaining challenge is, as you stated, to obtain the necessary foreign participation—the balance of the $1.7 billion.

We have been traveling and making a number of overtures. I led a trip this time a year ago to Japan and Korea to begin the formal discussions. One of our representatives in Japan at this very moment is continuing those discussions. We have had a high-level trip to Europe and to Canada. And we are exploring with other potential contributors. We are discussing the partnership approach with them, and there are a number of countries that are showing interest.

The funding profile in this report shows when these foreign contributions will be received and how much they will be. We will happy to discuss the details of international activities separately, but certainly answer generally any questions you may have in that regard.

Mr. Chairman, I would conclude by saying that we have an obligation to the American people to be bold and to do the things that will keep this country great. We also have an obligation to the American people to do it on time and on budget. This project is a bold project for the greatness of America's future. But this project is now also being run as it should be, and it will be on time and on budget.

[The prepared statement of Mr. Moore follows:]

PREPARED STATEMENT OF W. HENSON MOORE, DEPUTY SECRETARY, DEPARTMENT OF ENERGY

Mr. Chairman and Members of the Subcommittee: I am pleased to have the opportunity to testify before the Subcommittee on the Department's Superconducting Super Collider (SSC) program.

The SSC is a critical part of the Administration's initiative to strengthen the position of the Nation as a world leader in science and technology. It is the largest basic science project in the history of the Department. We recognize that effective management of such a large, complex endeavor is a great challenge, and we stand ready to meet this challenge. I will indicate the substantial progress we have already made and the plans we have to ensure that the SSC is completed on schedule and within cost. We are confident that the SSC will be a world-leading facility for basic research at the very frontiers of knowledge about the basic structure of the universe and how it operates, and that it will yield exciting discoveries and technological innovations that will likely affect major technological directions in the 21st century.

Already high energy physics research related to the SSC has industrial applications in several areas: supercomputers, plastics, electronics, fiber-optics, nuclear medicine and data processing. Superconducting magnets alone represent a $2 billion industry and are being used in over 200 hospitals for CAT (Computerized Axial Tomography) and PET (Positron Emission Tomography) scans and Magnetic Resonance Imaging.

There has been substantial progress on the SSC since the selection of the Ellis County, Texas, site and formation of the SSC Laboratory early in 1989 and the appropriation of first construction funds in the FY 1990 budget. Under the leadership of Dr. Roy Schwitters and the Universities Research Association, the management of the SSC Laboratory recently has been substantially strengthened with the appointment of Mr. Ed Siskin, who has 27 years of experience in the management of large projects, to the new position of General Manager, and the appointment of Mr. Paul Reardon, who has extensive experience in management of the design and construction of particle accelerators, as Project Manager. Earlier, the Department established an On-Site Project Office, headed by a Project Director, Mr. Joseph Cipriano, who has extensive large project experience and was the top civilian in the Naval Sea System Command. A very strong DOE and Laboratory management team

is now in place with a combination of major construction and technical project experience and resources to ensure that the SSC is built to the cost and schedule baseline.

This experienced team has already made its presence felt and is having an immediate effect in bringing the following accomplishments in on schedule and on or below budget. Specific accomplishments include: (1) award of the contract for SSC architect-engineer/construction management services to the team of Parsons-Brinckerhoff/Morrison Knudsen, which will oversee the design and construction of all on-site conventional facilities such as tunnels, surface buildings, utilities, and roads; (2) completion of the Supplemental Environmental Impact Statement and Record of Decision for construction and operation of the SSC; (3) completion of a Memorandum of Understanding with the State of Texas that outlines the principles that will govern the interaction between the Department and the State of Texas regarding its participation in the SSC project and its contribution of land and $1 billion; (4) transfer of initial land parcels to the Federal Government by the State of Texas as part of the land acquisition program by the State, which is running well ahead of schedule; (5) initiation of on-site construction of the Magnet Development Laboratory, which will be completed and in operation this summer; (6) selection of General Dynamics and Westinghouse, respectively, as leader-follower contractors for the engineering development, prototype production, and production of a small number of the collider dipole magnets; (7) identification of two large, general-purpose detectors (the Solenoidal Detector Collaboration and L*) for further design, with both detectors including major participation by foreign scientists; (8) completion of the "Report on the Superconducting Super Collider Cost and Schedule Baseline"; and (9) successful testing of four models of the new 50-millimeter design dipole magnets; these short, 1.8-meter models consistently demonstrated performance significantly above the required operating currents and, thus, were highly successful; the first full length, 15-meter dipole magnet is planned to be tested in the fall of 1991.

Another very important activity during the last year has been the initiation of the Department's formal efforts to seek contributions from potential partners. A plan entitled, "A Framework for International Participation," was developed last year in cooperation with the Office of Management and Budget, the Office of Science and Technology Policy, the National Security Council, the National Science Foundation, and the Commerce and State Departments, as well as with other appropriate agencies within the Executive Branch. The plan sets out our international objectives, the policy and regulatory framework in which the international negotiations will be conducted, and an overall strategy for establishing appropriate international agreements. This strategy builds upon the experience of the U.S. High Energy Physics program in international cooperation and the experiences of other major research laboratories in Europe and Japan.

This partnership concept is based on a premise of equity participation and true partnership with foreign contributors to the SSC. The State of Texas, as a major contributor to the SSC project, is already working with the Department as the first major partner. Discussions are underway with potential foreign partners to develop specific proposals for participation and to begin negotiating agreements on the magnitude and type of contribution.

Last May and June, I led a formal delegation to South Korea and Japan with a letter of invitation from President Bush to join with the U.S. Government in the SSC project. Discussions are underway at various levels with both Japan and South Korea to explore their areas of interest. Last fall, Assistant Secretary John Easton led advance teams to Europe and Canada to outline our partnership approach and explore areas of interest. Discussions are continuing in both arenas, with particular interest on the part of Canada in becoming a significant partner, possibly even contributing a major system, as well as other materials and components. We are also in the process of finalizing an agreement with India for its longstanding commitment of $50 million to the SSC. In addition, discussions are underway with the Soviets to explore areas for their participation, including major components and subsystems. Other nations are currently being considered as well.

In the area of detectors, both collaborations identified for further design and approval would include major participation by foreign scientists and substantial cost sharing by other countries.

Now I want to address, in-depth, what I consider one of the most important accomplishments of the past year, the Department's "Report on the Superconducting Super Collider Cost and Schedule Baseline," which was released in February 1991. This report represents the culmination of an extensive effort by the SSC Laboratory to develop a site-specific conceptual design, along with cost and schedule estimates

for the SSC, and the efforts of the Department to thoroughly review the Laboratory's work, to reconcile differences noted by three independent review committees, and to develop a credible cost and schedule baseline for the SSC. The report carefully documents the history of the conceptual design of the SSC and the earlier cost and schedule estimates. It describes the site-specific conceptual design developed by the SSC Laboratory in 1989 and 1990, discusses the major changes from the earlier 1986 conceptual design, and discusses the methodology used in developing the SSC cost estimate. It provides a description of the Department's cost and schedule baseline along with the rationale used to arrive at that baseline.

In December 1989, the Laboratory submitted preliminary information to the Department proposing changes to the 1986 conceptual design that would likely increase the total project cost of the SSC from the previous Department estimate of $5.9 billion in as-spent dollars (i.e., including an allowance for inflation) into the range of $7–8 billion (as-spent). The revised design was specific to the Texas site, reflecting advances in accelerator and detector design and technology, and recent experiences with magnet performance at other high energy physics facilities around the world. Specific changes included increasing the magnet aperture diameter from 40 to 50 millimeters, increasing the collider ring circumference from 52 miles to 54 miles and a doubling of the injector energy from 1 to 2 trillion electron volts (TeV). The resulting design is more conservative and will ensure a more rapid commissioning and reliable operation of the SSC.

In light of this new information, Secretary Watkins requested a review by the High Energy Physics Advisory Panel to assess the overall scope of the SSC and the scientific potential of the facility as a function of beam energy for beam energies below 20 trillion electron volts (TeV). A blue ribbon High Energy Physics Advisory Panel subpanel recommended strongly that the SSC energy be maintained at 20 TeV and concluded that implementing the design changes proposed by the SSC Laboratory would ensure confidence in reliable and timely operation of the SSC. The subpanel's report was unanimously endorsed by the High Energy Physics Advisory Panel. After carefully reviewing this advice, Secretary Watkins reaffirmed that the SSC was properly scoped at 20 TeV and that the design changes proposed by the SSC Laboratory were necessary. The preliminary estimate of a total project cost in the range of $7–8 billion was discussed by Secretary Watkins and other Department officials during a number of Congressional hearings on the FY 1991 budget.

In June 1990, the SSC Laboratory completed its Site-Specific Conceptual Design Report along with cost, schedule, and funding profile estimates. This documentation served as the starting point for the Department's process of developing an SSC cost and schedule baseline. It set forth a total project cost estimate of $7,837 million (as-spent) with completion by the end of FY 1998.

In order to ensure a thorough evaluation of the SSC Laboratory's design, cost, and schedule estimate, the Department commissioned three independent reviews. These reviews included the customary reviews by the Department's program office (the Office of Energy Research for the SSC) and the Department's Independent Cost Estimating staff. To ensure a completely independent and critical review of both the Laboratory's estimate and the Department's review process, Secretary Watkins requested a third, special review by the High Energy Physics Advisory Panel.

As a result of a thorough evaluation of the cost and schedule baseline proposed by the SSC Laboratory and the recommendations and comments of the three independent review committees, the Department reconciled the major differences and developed a baseline cost and schedule estimate for the SSC. The increases to the total project cost suggested by the review committees were largely in the area of contingency allowances to cover estimated costs for technical uncertainties and for schedule delays that could possibly occur during the course of the project. Concerns were also expressed about the realism of the schedule and funding profile. The Department's Independent Cost Estimating staff, in addition, raised a number of concerns about what costs should be included in the total project cost. The findings of each of the review groups are documented in the Department's SSC Cost and Schedule Baseline Report.

The Department asked the SSC Laboratory to revalidate base-cost estimates in all areas where the review committees expressed concerns. The Department reached decisions on adjustments to the base-cost estimates, the contingency allowance, a schedule extension, the detector allowance, and escalation rates. The Department established policy positions with regard to treatment of foreign contributions to detectors, Laboratory operating costs, DOE On-Site Project Office costs, and land costs. The rationale for these decisions and positions are presented in the baseline report.

The Department's baseline for the SSC identifies a total project cost of $8,249 million (as-spent), with project completion by the end of FY 1999. The detailed features

of the baseline are documented in the Department's baseline report. The baseline incorporates changes to the base-cost estimate for some elements of the construction project, a schedule extension of one year to accommodate a less aggressive funding profile which was viewed as necessary due to budget and political constraints, and a contingency allowance of $843 million. We believe that these adjustments produce a baseline that is generally consistent with the advice of the Energy Research Review Committee and the High Energy Physics Advisory Panel, and takes into account many of the concerns raised by the Independent Cost Estimating group.

The baseline is technically feasible. It will provide a high energy physics laboratory capability that meets the scientific objectives of the SSC and that results in a facility that can be commissioned readily, while operating with high reliability. It establishes a credible total project cost estimate and an aggressive but cost-effective schedule. The baseline funding profile reflects a balance between meeting the schedule objectives of the program and the current budget constraints.

The baseline cost includes a contingency allowance of $843 million (as-spent), which should provide a more than adequate contingency envelope for effective execution of the SSC project. This contingency allowance should provide for appropriate tradeoffs and responses to any reasonable set of technical and schedule uncertainties that might arise. The extension of one year in the baseline schedule to FY 1999 provides schedule flexibility and a more prudent ramp-up of funding. The combination of the revised schedule and the increased contingency allowance from that initially proposed by the SSC Laboratory prudently reduces cost and schedule risks. The baseline furthermore ensures reliable and flexible operation through a more conservative design approach by the SSC Laboratory than that of the conceptual design of 1986.

I believe the Department's "Report on the Superconducting Super Collider Cost and Schedule Baseline" provides a clear and consistent picture of how cost estimates for the SSC project have evolved, the present baseline cost and schedule, and where the project is going. This report becomes the reference against which the Department and the SSC Laboratory will manage the project and report progress and status to the Congress. The Department's baseline provides a cost-effective basis for planning and executing the SSC in a manner that will ensure that the scientific objectives of the SSC will be achieved and that it will be completed on schedule and within funding. The Department and the SSC Laboratory management are fully committed to meeting these goals. Strengthened management teams are now in place at the Department and at the SSC Laboratory. Strict, formal change control procedures are in place and the Department is retaining full control of the expenditure of contingency funds.

As of the end of FY 1990, project costs were underrunning the budget by $31 million. Experience to date in FY 1991 continues that favorable trend. Numerous opportunities for further cost savings have been identified and are being aggressively pursued. An Architect-Engineer/Construction Management contract and leader/follower contracts for the collider dipole magnets have been negotiated below estimated baseline costs. In addition, the State of Texas has purchased an existing facility for use as SSC office and laboratory space at a projected savings to the project of $10 million. All major project activities are on, or ahead, of the baseline schedule and we expect that other on-going activities will lead to further cost savings.

In closing, I would like to note that the cost and schedule estimate presented in the Department's baseline is intimately linked with the funding profile indicated. Any change in funding profile will have an impact on schedule and total project cost. Receipt of funding as indicated in the baseline funding profile will enable the Department to execute the project as estimated, with confidence that we can control the project so that there will be no cost overruns or schedule delays. Receipt of funding is also important to give confidence to potential foreign contributors that the project is on a sound track and that their commitment is timely. Any reduction in funding means delay (a rule of thumb is about $1 million per day) and delay affects the ultimate cost and success of the SSC.

Fiscal Year 1992 is a critical year with a significant increase in Federal funding to $533.7 million, as indicated in the Department's FY 1992 budget request. This increase is key to getting critical project activities underway in FY 1992. The activities in the balance of FY 1991 and FY 1992 will substantiate the key cost elements in the baseline estimate particularly in the areas of tunneling and conventional construction, accelerator design and superconducting magnets, culminating in the completion of the accelerator systems string test in the fourth quarter of FY 1992.

That concludes my statement. I would be happy to answer questions.

Senator FORD. Thank you, Mr. Secretary. I have a lot of questions, and I do not want to take too much time. But, Dr. Bromley, even some big science supporters argue that $8 billion plus is too much money for one project. A lot of small science projects could be funded with that kind of money. And I realize that sometimes it is difficult to place big science projects in priority, but when funds are limited this side over here is required to make a decision on priorities. One has to do that. That is one of our responsibilities. And I know that several science groups have been able to make some priority decisions. They rank the SSC as important but not as important as individual research projects, the space station, SDI, the space plane, and the human genome project.

What priority would you give the SSC when you compare it to other big science projects such as the human genome project, the space plane, the space station, et cetera?

Dr. BROMLEY. Well, Mr. Chairman, I would have to say that the list you have given—the SSC, the genome project, NASP, and SDI—represent a remarkably diverse set of initiatives. The SSC, as both Secretary Moore and I have said, is the largest project that has ever been undertaken in the physical sciences. The genome project is the largest project that has ever been undertaken in the life sciences.

Let me just focus on those for a moment, because they most represent the basic sciences on the list you have given me. Each year when we come to you, the challenge we have, Mr. Chairman, is that of balancing on the one hand the support for scientists and engineers to do what they want to do today against investing in the facilities that will take these same scientists and engineers to where the frontiers are going to be 5 and 10 years from now.

In the cases of both the SSC and the genome project, we are making these investments in defining the future frontiers. The SSC will clearly define the frontiers of investigations in physical sciences through the end of this millennium. The genome project is going to provide the framework for what I anticipate will be an explosion of biological understanding, again some 10 years downstream. But it is going to take these same people we are talking about.

The genome project, incidentally, is not big science. It is being done almost entirely by individual professors with a few postdocs and graduate students sprinkled all over the world. There is central coordination, but it is small science. It is important to emphasize that distinction.

Moving on, SDI is of course a major piece of our national security activity. It also involves fundamental research of a variety of sorts, and a significant amount of that is being done under contract by investigators in the Nation's colleges and universities.

The National Aerospace Plane I would put in a different category. In the program thus far, we have made very substantial progress in both materials science and in computational science. In the process, I believe, sir, that we are doing the kind of work that is essential if we are going to maintain America's aerospace industry at the frontiers of world activity in that field, a position that it has enjoyed for a great many years.

If I look at these four projects, they are in entirely different areas. You are quite correct, sir, in saying that a number of fields of science have found it possible to prioritize within their individual sciences. I was involved in such an exercise—one of the first, in fact—back in the early 1970's in my own field of physics. Most recently the astronomers have succeeded in what I think is an outstanding piece of work in prioritizing their needs.

There is, sir, however, the fact that as you move farther and farther away from any homogeneous community, there is a vastly greater difference and a vastly greater difficulty in making priority decisions between projects that are fundamentally different. Frankly, sir, I think that the four you have listed—the National Aerospace Plane, the genome project, the SSC, and SDI—typify precisely a point that you made just a moment ago, namely that these decisions cannot be made within the framework of science. They fundamentally end up being political decisions, and as such are ones that you and your colleagues have to make with the best input we can give you.

Senator FORD. Well, Doctor, you gave me a hell of a long no answer. What—I asked you for help, and all you did was explain that these are great projects. So, you do not help us in making a selection. They are all equal in their own right maybe. But let me just tell you the CRS says that the human genome is a mega project. I have here the CRS report to Congress dated February 19, 1991, and they say it is a mega project. And you say it is a small science project.

Dr. BROMLEY. It is a collection, sir, of activities carried out by individual scientists.

Senator FORD. Well, anyhow, so you say it is a collection. Now, give me some priority, Dr. Bromley. If you had to sit there—the money is coming from the same place. There is not going to be anymore money. Now, tell me which one of those projects you would give priority to.

Dr. BROMLEY. Mr. Chairman, it is the administration's position that it is in the national interest that we proceed with all of those projects.

Senator FORD. And how much new tax money is the administration going to propose to pay for it?

Dr. BROMLEY. That, sir, is not in my area of science and technology.

Senator FORD. Well, Dr. Bromley, I could have read your statement then and got as much out of it as you are giving me. Now, I am not trying to be smart about it, but you are here as head of the administration's science and technology group and we are trying to get some information. And you will not make a choice and you will not say where the money will come from. You are representing the administration. Is that correct?

Dr. BROMLEY. I am representing the administration. Yes, sir.

Senator FORD. All right. Well, I thank you for as much as I have gotten. How will the SSC aid U.S. competitiveness?

Dr. BROMLEY. Secretary Moore has already addressed this in part. Whenever you push technology to its limits, as you do in a frontier project of this sort, you have historically developed entirely new industries—the superconducting industry is a particular

case in point. Our ability to make the superconducting magnets that are present in just about every modern hospital is purely a result of the fact that particle physicists attempting to build their research tools at places like Brookhaven and Fermilab and Argonne did the original research and development. All of that has come from just the same kind of activity that we are proposing as part of SSC.

Senator FORD. How will the SSC aid U.S. competitiveness?

Dr. BROMLEY. I have no way of answering that in detail——

Senator FORD. I am asking it again. I want——

Dr. BROMLEY.—Mr. Chairman, because it is a basic research project, a fundamental research project. Other than giving you a general answer based on the best history we have, I cannot do that.

Senator FORD. What new technologies do you think SSC will produce?

Dr. BROMLEY. It will certainly enable us to produce more effectively and more cheaply superconducting magnets. We obviously are going to learn a great deal about producing very large volume vacuum systems. We are going to be developing a tremendous amount of radio frequency gear to drive this accelerator. The instrumentation that goes in the defectors that Secretary Moore talked about is at the absolute frontier of modern technology. These detectors will turn out information at a rate that we have never seen before, and this provides a major impetus to modern computer technology, to modern data-handling technology, and to the whole spectrum of electronic instrumentation that is involved in a facility of this kind.

Senator FORD. If we waited 3 years to begin the full funding for SSC, what exactly would the United States lose?

Dr. BROMLEY. Probably the most important thing, sir, is the productivity of a whole generation of people in this field who now are planning 10 years into the future to do experiments with this facility. If it is held up for a number of years, it means that this work will not get done.

Senator FORD. Do you mean, if we hold it a couple of years without fully funding, I mean, some funding, you mean, we will lose all those that are now working in the field?

Dr. BROMLEY. No, not all. But if the project does not start with an effective jump start, to put it crudely, it is going to be very difficult for us to convince our foreign collaborators that we really mean business with this. It will be extraordinarily difficult, as Secretary Moore has indicated, for us to get what is now a very critical foreign participation in this project. Delaying it or starting it up at a very low level, in both cases, would have the effect of essentially killing the project because it would make it impossible for us to get the foreign contribution that is an essential part of the administration's funding plan.

Mr. MOORE. Senator, if I could add, our project managers have indicated to me that they have calculated that every day's delay in finishing this project runs about $1 million in increased costs.

And so a 2-year delay, you can translate that very carefully into better than $700 million increased costs, assuming you are able to build it in the 2 years.

I share with Dr. Bromley, as he is well aware, we are well aware of the international science community watching this project to see whether or not to participate. We are at a very critical point, when the major countries that are looking at this, the Soviet Union, Canada, Europe, Japan, are waiting to see what happens in fiscal year 1992, quite frankly.

As a matter of fact, they may well be in this audience right now. They generally have been when we have testified before, watching this project. And we do not think it is a competing project, quite frankly, but there are some people in the world who think there is a proposed project in Europe that is not as far along as this that would be a competitor.

And if you stretch it out that far, you may well make it possible for the competitor project, as I say, we do not view it as a competitor project, but some people do, for the competitor project to be built.

And that means then you really would not get the foreign participation. We would wind up with an incomplete project here, or coming back to the Congress asking them to fund the whole thing which we do not want to do. That means then we have the losses.

And one thing you mentioned, Mr. Chairman, I would like to mention, which is, what do we get out of this? We have looked at this very hard, and what we are seeing already with just the building of it is creating a spinoff of applied technology. It is already happening.

I was touching on the things that are already happening in the American business sector because of the money we have spent so far.

And secondly, we hope that American businesses will come into this laboratory and watch the work going on and take that basic research out and apply it. They are more apt to do it if the laboratory is located in Texas than if it is located in France.

And thirdly, this is an educational institution. There are going to be Ph.D. doctoral candidates from the United States and some from around the world studying there. We are going to have a better chance for our students to be involved and our teachers to be involved in this laboratory if it is located in Texas than if it is located in France or some place else. And so there are some very practical reasons why this ought to be here for the benefit of the United States.

Senator FORD. Well we have already spent $500 million, how much more do we have to spend to get foreign nations to commit?

Mr. MOORE. We believe that in fiscal year 1992, you are going to see, if we receive the funding we need——

Senator FORD. Another $500 million——

Mr. MOORE. We think that will be what it takes, yes, sir, that those countries are watching.

Senator FORD. Plus, Texas, $130 million and so forth.

Mr. MOORE. They have told us from the very beginning, when I was in Japan last year, they told from the very beginning, we want to see that you folks are really going to build this.

This is really the major construction money, the first major construction money we are looking for is fiscal year 1992. We have gone through the design stage. And now we are at the point where

we are ready to start the construction stage, and that is what you do in fiscal year 1992. And that is what they are watching to see if it happens.

They know that is the major test for the Congress and the will of the American people, and they are not going to put up their money until they see us pass the bar.

Senator FORD. Most of this research was done at the FEMA lab, is that not correct?

Mr. MOORE. Fermi.

Senator FORD. Fermi, I am sorry.

Mr. MOORE. And Brookhaven, and a number of other institutions.

Senator FORD. Yes. But anyhow, many foreign nations invested funds and sent their people here to work at these places, is that not correct?

Mr. MOORE. There are foreign nations at the Fermi Laboratory, yes, sir.

Senator FORD. And made investments into the research that was being developed there. Now do they not have the same information we have, for all practical purposes right now, those that were there and were involved in the research and paid their good money to be a part of it. Do they not basically have the same information that we have?

Dr. BROMLEY. I would suggest that they do not, Mr. Chairman, because there is a very great difference between coming in as a visitor and watching something work and having been there at the creation and having gotten your hands dirty making it work. The very fact that we are involved in the actual construction, that we see how to correct problems as they arise, gives us a level of know-how that does not transmit to the casual visitor or the research visitor.

Senator FORD. Well, I understand that, but once you complete a product, you can take it from there and go with it, can you not? You do not have to go back and get your hands dirty to understand the products have been completed to move forward with.

Dr. BROMLEY. I am pretty well convinced, Mr. Chairman, that you learn very little in this world without getting your hands dirty. I am an experimentalist.

Senator FORD. Well, you might get your hands dirty if you cannot give any answers.

Mr. MOORE. Senator, I think that, as I was trying to elucidate, you are correct in the sense that ultimately the basic research in one of these laboratories like this, just like the ones we have now, basic research now, ultimately that is going to find its way into scientific journals and whatever.

And if that is what you mean, are they not going to get that information, eventually they will.

Senator FORD. Well, Henson, I think they already have basic information because they were there from the beginning when I visited there and you had it up on the chalk board, the individuals, and the countries, and how much money was put into it. And they were there almost from the beginning.

So a lot of them have gotten their hands dirty in this project, and they have taken that knowledge with them when they left there.

So what I am concerned about is that we are moving awful fast, and we are spending an awfully lot of money, and there are a lot of questions from other parts of the scientific community about what we are doing. And when we try to get answers, to find out if one project is more important than another, we cannot, and so we just say we want to fund them all.

We do not have any more money this year than we had last year, and we are going to have to start shifting money around, and we are talking about $533 million this year, and every time we get an estimate it is higher, even from your agency, even though you think you have it in hand now.

So I am very concerned about, do you go ahead and build the tunnel now, when you do not have the magnets on board. And we have the German outfit that indicates that we are moving too fast. You have to put all those things together before you start building the tunnel.

So we are starting the big construction, and we do not even have the magnets developed completely. And far be it for me to know what the heck is it all about, but I have to try to learn and ask silly questions as a country boy, to try to understand how I am going to cast my vote to spend this money as it relates to America's competitiveness. And I get no answers.

Mr. MOORE. I am trying to answer them, sir.

Senator FORD. I know, and bless you, I wish there were more like you around here.

Mr. MOORE. Senator, there are no silly questions, just silly answers. And let me try once again to take a crack at what you are saying.

Senator FORD. Let me try some questions and maybe I can move into the arena with you, Henson. The total cost for SSC done by your office of independent cost estimate, it is called ICE, is $11.8 billion. The ICE report states that "DOE's estimate for the SSC is both unrealistic and unachievable," and that is a quote.

The report also states that it does not reflect a worst case scenario, that is $11.8 billion does not. An estimate for a worst case scenario could be substantially higher than the $11.8 billion.

Now we keep accelerating. We started out at less than $4 billion and then we went almost to $8 billion, and now we are at $11.8 billion, and we just keep moving, and it keeps eating into the amount of monies available for basic research or whatever around the country.

So the difference between your estimate and that of your own independent staff is almost $4 billion. Now explain that large difference to me.

Mr. MOORE. Mr. Chairman, I will try.

Senator FORD. That comes out of your group, you know, ICE does. That is not ours.

Mr. MOORE. This book explains it in detail, to the very word. There are not secrets in this, no mysticism, no lack of understanding——

Senator FORD. Well, how accurate is ICE's prediction rates?

Mr. MOORE. We think—we had three studies done, and we do not think that they are any more accurate than the others. We think they have made some mistakes.

For instance, all of the groups, the major difference between what the laboratory said this was going to cost and the others was in contingency. How much money do you put aside in case something does not come in like you want it?

And what we are telling you right now, so far we are coming in with a contingency we have selected at that or below, have not had to use it as a matter of fact, any of it. So we think our estimates are better.

Number two, they have added some things to it, substantial amounts of money that were really not part of the total project costs. They simply say, we disagree with your policy, we think it should.

Give you an example, they include in here the DOE site office. We have never included that in any project anywhere in the country, and when we put Government people in the ground to manage it, that is a part of the cost. That is part of the overhead of running the Department of Energy. It has never been allocated to a project.

So we disagree with them on some things like that, they are just out of the ballpark——

Senator FORD. That could not be a whole lot, could it?

Mr. MOORE. Well, it means, that particular figure was not but $31 million, but they say the cost of the land ought to be in there. Texas is giving us the land, all of it, no matter what it costs. So what difference does that make?

Senator FORD. You ought to take it to the Taxpayers' League and let them figure out what you are doing. They want to factor everything in, and so that is part of the cost to the taxpayer, whether it is Texas or up here.

So you are excluding $1 billion from Texas, is that right?

Mr. MOORE. No, we are excluding the cost of the land in Texas.

Senator FORD. Well, how much is that?

Mr. MOORE. Well, it depends on what it winds up coming in at. Texas agreed to furnish it, no matter what it costs.

Senator FORD. So the cost, ICE has reflected in——

Mr. MOORE. They say $70 million.

Senator FORD. Yes.

Mr. MOORE. Is what they say. We think they are off, it is going to cost more than that.

Senator FORD. Well, say it is $100 million, but you do not count that in your estimate?

Mr. MOORE. There is no point in counting it——

Senator FORD. Are you going to count foreign money?

Mr. MOORE. It depends. The foreign money that is given towards the building of the project, yes. That is part of the total $8.249 billion cost. In some cases, detector costs are not counted and never have been counted in projects because nobody knows what those things are going to cost, and many of them are not even finished until the project is finished.

Senator FORD. But the taxpayer will pay for that out of the budgetary process, to the Department of Energy?

Mr. MOORE. They will pay only the amount we have asked for and no more than that.

Senator FORD. Oh, I understand, $533 million?

Mr. MOORE. No. It is more than that. It is—let us see, detectors are what? $910 million.

Senator FORD. How many agreements have you been able to work out and how much is the foreign contribution so far? Will it be in cash or in kind?

Mr. MOORE. The only agreement that has been worked out so far is with the country of Korea. The value that they intend—excuse me, with India, and the amount that they intend to contribute is in the range of $50 million.

We are working out now the details of how that is going to be done. They are now working on in kind contributions for the first installment of that.

It is our expectation that a great amount of the foreign contributions that are going to be made to this will be in kind. We are asking all the countries with which we deal with for grants as well, not just in kind. That is a matter of negotiation with each country you deal with, and we are in those negotiations with India, with Korea, with Canada, with the Soviet Union or will be, and Japan and a number of other countries along those same lines.

Senator FORD. Most of them will be in-kind contributions?

Mr. MOORE. I will say that probably most of the contributions you are going to see are going to be in-kind, equipment and services, all of which has to be part of the project costs to count towards this $1.7 billion that we owe.

If they give us something like some fancy flag pole that we do not have in our budget, that is not going to count towards the total project cost.

Senator FORD. When will it become too late to get the foreign contributions?

Mr. MOORE. As a matter of fact, most of the countries probably are not going to contribute until late in the process. Now this is just a guesstimate on our part in talking with them and dealing with them.

They want to see that this one is going, it is going to be the best, and there is not going to be anything. Then they are going to contribute their scarce resources. In those cases, those countries will probably come in for cash grants because by that time all of the goods and services will have been purchased.

And so a lot of them will come in near the end. Some of the major contributions will come in about the middle.

Senator FORD. When it is too late to get a commitment?

Mr. MOORE. It is never going to be too late. If any country wants to come in and give us a grant when this thing is, when construction is finished, we will be glad to talk to them about it.

Senator FORD. But, Henson, the amount of money that we are looking at and is predicated on foreign investment, the total cost, and if you do not get that, when it is too late for us to secure a commitment, when we will be obligated for the foreign commitment?

Mr. MOORE. Mr. Chairman, I understand what you are getting at. Page——

Senator FORD. I hope you do. I am having a hard time getting what you are getting at.

Mr. MOORE. I am trying to answer your question. On page 62 of this report, we lay out the profile for you, year-by-year, to come up with this $8.249 billion, what the total amount is; how much of it is Federal; how much of it is non-Federal, meaning Texas and foreign sources. We lay that out.

That gives you an idea of exactly what we are expecting to be able to receive in each of the fiscal years. Now you can ask this question each year, and obviously, the further down we go in the fiscal years, we are going to have increasing difficulties in getting appropriations if we have not received the foreign participation that you are asking about.

For the year, fiscal year 1992, we are talking about $150 million, counting Texas and foreign. We believe we are going to accomplish that without any difficulty for fiscal year 1992. During the year, 1992, by the time we have a hearing like this in fiscal year 1992, we are going to give you a much better picture of what it looks like for fiscal year 1993, 1994 and 1995, as we believe we are going to be at the point then of being able to actually close negotiations with a number of countries with whom we are talking.

But they are watching fiscal year 1992 as the construction money is the key.

Senator FORD. All right. Say you get your $533 million or whatever it might be, I think Dr. Bromley said $534 million. Say if you get that, then you need $150 million non-Federal. All right. What if they renege on their commitment?

If they commit to you in 1992, is that for the total project?

Mr. MOORE. Most of them are going to commit when we deal with them, like we have Texas, for a total amount of money they are going to contribute to this project.

Then we base how we spread that out. We negotiate with them and what payments they are going to make. So far the only partner we have in that regard is Texas and Texas has done exactly what they said they were going to do each year. We have negotiated with them, and they have made the contributions.

With each country we deal with in the future, it is the same thing. We are going to agree with them on a total contribution, a method of payment of that contribution and in what time frame that contribution is made.

Senator FORD. I am sorry. But Japan is supposed to maybe give the magnets. At what point is too late to get the magnets from them?

Mr. MOORE. When we have actually let out the industrialized contract to build them, and that will not occur until fiscal year 1994.

Senator FORD. When will you let the contracts to build the tunnel?

Mr. MOORE. You mentioned that a moment ago. The only tunneling we anticipate in fiscal year 1992 is that at the end of 1992, a very short section of tunneling, short enough to prove up the technology we intend to use to dig the tunnel, and secondly, to begin to be able to lay a short string test in it to be sure the magnets work. The major tunneling does not being until fiscal year 1993.

Senator FORD. I am not sure a country boy from Yellow Creek can pronounce this right, but the German Heraldesy——

Mr. MOORE. Yes.

Senator FORD. Report states that it is critical not to underestimate the time needed to develop the magnets or rush to production. It seems to me that DESY may be a good source of information on this. I see Dr. Bromley shaking his head, since the magnets for the accelerator in my opinion are the only ones that have been industrially-produced, I believe also that the Isabelle project was terminated due to various problems, including design difficulties and delay in fabricating magnets.

So you know, there are lots of things here, and I am looking at money.

Mr. MOORE. So are we.

Senator FORD. Making a commitment, and I just hate to see such a rush to construction of the tunnel in the fourth quarter of 1992.

Mr. MOORE. How long is the tunnel section we are talking about building? We have about 2½ miles.

Mr. CIPRIANO. We have about $30 million in the fiscal year 1992 request would go toward tunneling.

Mr. MOORE. Only $30 million, that is an insurance policy, to be able to test and be sure before you do the major tunneling, you know what you are doing. This test needs to be done.

Now let us talk about the magnets. You brought that up. We are in contact. This is a very small community worldwide, as Dr. Bromley can talk to you better than I can, and we are dealing with these scientists around the world in terms of magnet design.

They are being built right now up at Brookhaven Laboratory. They have been tested. They have proven out and are meeting the specs. They are doing, as a matter, as good or better than the specs indicated, and we are going to be ready to put those out for industrial construction when the time frame calls for it. We are not rushing it.

Senator FORD. Well, here is the GAO report, have you seen this?

Mr. MOORE. It just came out today. We had a chance to look at it a few minutes ago.

Senator FORD. Well, it says that the magnet development schedule is compressed with overlapping development stages, and little or no time available between stages for resolving problems, and according to an SSC laboratory official, when problems arise in one development stage, they will be resolved in the next one.

Mr. MOORE. Well, we have looked with that, and I have dealt with Mr. Siskin and Mr. Cipriano on that comment. We strongly disagree. What they are advocating there is rather than doing anything in parallel, you do everything sequentially. You take it one step at a time and stop and test that stuff and move to the next.

You do that, we are going to delay about 2 years the building of this project, and about $700 million to $800 million for no appreciable improvement in quality control. We do not think they know as much about managing this project as these folks do, and we just do not think that is an accurate criticism.

Senator FORD. I have a lot more questions. I will send them to you in writing.

Senator Craig, I apologize for the delay.

Senator CRAIG. Mr. Chairman, you do not need to apologize. I have been sitting here enjoying it and also increasing my understanding and knowledge of high energy physics and what you all are going to do. I have not been as critical of SSC as you, but I have been critical. I have watched it very, very closely, because I think any time when this country commits itself to this kind of an investment, we need to know where we are going and what we are going to accomplish when we get there.

So, for you, Dr. Bromley, or for you, Henson, as I ask a couple of questions here, I will direct them to both of you in general. Many questions have already been asked. I wanted to know the number of universities that are involved at this moment. You have asked that.

I think all of us are extremely concerned about the spinoff. I guess I am concerned. I grow less concerned everyday. For me to ask what it will be now would be like me to ask at the beginning of the space program what the spinoffs were going to be. And frankly, anybody sitting at the beginning of that could never have said what they all are, because we are still experiencing them. We watched them working in Desert Storm and you could track it all right back to the 1960's and the space program and some of the work that went on at that time.

And so I think anytime we run at a project with the kind of resources that we are running at this one with, the spinoffs are almost unimaginable at this point in time. But there are some concerns and they relate to money and tight budgets. I think as a fiscal conservative, I have got to be responsible to my constituents in tracking this and making sure it happens in the right way.

What is the percent of foreign participation that is anticipated in the total——

Mr. MOORE. $1.7 billion. That would be the—it has never been in law anywhere. This has been something that when the Reagan Administration unveiled the project, they said they anticipated that one-third of the cost of the project would come from non-Federal sources. And everybody seems to be operating off that. The Bush administration is as well.

Senator CRAIG. That is the general guideline? One-third?

Mr. MOORE. One-third. Now, that counts—that one-third includes Texas. That is a non-Federal source. So if you take the 8.249 and subtract out the Texas, you are looking at roughly 1.7 that we have to obtain from other non-Federal sources than Texas.

Senator CRAIG. What does a non-Federal and in this instance, my question would be what does a foreign source buy? And by that I mean a participating foreign Nation as a major contributor—are they a full partner, a full beneficiary or do they buy a designated piece of the action and, therefore, a piece of the findings? How do you arrive at the arrangement by which a foreign partner would be involved and benefits?

Mr. MOORE. Let me divide the question into two parts. I will take the first. And Dr. Bromley I think can handle the second part better than I.

We are now looking at what we want as partners in the building of this project—the building and the operating of it. That is putting up the money towards the total project cost—the TPC. That is the

8.249 billion; 1.7 billion of that will come from non-Federal sources other than Texas. We have now been working on a partnership agreement that we would extend to them based on their level of contribution. Certain partners are unable to do certain things. They have a greater say in how it is run—how it is operated.

Working on that now, we are negotiating that with the various countries that are looking at this. Most of the countries that have looked at it seem very pleased. And the United States has not had a history of international projects like this on American soil. And so they are looking at us, saying what are you talking about? What do you mean here? We are saying such things as a committee—an international committee—that would have represented on it Dr. Bromley and Department Energy and science advisors of these countries as well as Texas that would discuss in major terms how we are getting along, how we are doing, any problems.

We are talking about actual advisory committees on the site down there that have guaranteed membership of these member countries and the overseeing of the running day to day of this project, and the selecting of the projects that will be run there.

So that is the first level, and that is the level I am interested in right now is the actual creating an international partnership that they will contribute to or they will be partners of the United States—several levels of partnership, depending upon their level of participating. And several powers go with that—not a great deal different than a partnership agreement in the business world. You may be a 10 percent partner. You may be a 30 percent partner, depending upon the amount of the contribution that you are making to this project.

Senator CRAIG. That is a profit benefit in the business world.

Mr. MOORE. Well, in this case it is a matter of what they are putting in. And likewise we equate that then the power of say in the running of this project.

Senator CRAIG. Okay. You have discussed with me the relationship of input. I am also extremely interested in the relationship of the end product.

Mr. MOORE. That is where Dr. Bromley comes in. That is done on a scientific basis. There are numerous examples. As a matter fact, every laboratory has international collaboration once they are built, and that is a very common and more easy thing to predict. There we are just following what has been done before. And Dr. Bromley can talk to that. That does not count towards the TPC, I might add. That is in the operation of it or the fitting out of the detector halls and whatever, which, beyond the $910 million we have in the budget for detectors, do not count. Those contributions would not make them partners. Those contributions just allow them to be users of the facilities under the guidelines set by the partners.

Dr. Bromley.

Dr. BROMLEY. Well, what Secretary Moore is focusing on is the construction of the fundamental base facility that will produce the beams and let them collide. The next phase, where we already have very widespread experience back over decades, is where other countries come in and pay for a very large fraction, in some cases, of the development of the major detectors that are used to study

the events that occur. These detectors can be very large and can cost in the $50 million to $100 million range.

You asked the question, what do they get out of it? I believe that they get several things out of it. First of all, they get access for their scientists to the absolute frontiers worldwide. They get training. They get exposure—there is no question—to our technology and to our equipment, which in many cases they take home.

But I would emphasize that it is not all one way. For example, for a number of years at Fermilab, we have had as many as 50 senior Soviet scientist working actively with American groups. They have not only come over here and stayed for 18 months, 2 years, at a time, but they have brought literally millions of rubles worth of equipment which, having been used in one experiment, remains as part of the laboratory arsenal of equipment that can be used by anybody at the direction of the laboratory management.

This will very definitely be the case with the SSC, because we already see massive international group structures being formed to develop the detectors, and these will be the $100 million-type detectors that will be installed. Once they are installed, they will then be used on the basis of decisions made by program advisory groups.

This is something that people have not fully understood. On any of these big international facilities, there are program advisory committees that are comprised of some of the most distinguished members of the community of particle physicists worldwide. They meet on a regular basis, and the folk who wish to do experiments, who wish to use this facility, make presentations to try to convince the program advisory group that they should be allowed to operate and use the time available rather then someone else. These are truly international groups that make their decisions on purely scientific bases. Once those decisions are made, time is assigned on the accelerator.

Clearly, what people get out of it is what we get out of basic research anywhere. One gets new understanding. One gets training. One gets education, and I would like to think in international science, one gets something that certainly is important and that is open channels of communications—person to person, institution to institution—that can be broadened later on to cover a great many more things.

Senator CRAIG. Construction will start when?

Mr. MOORE. Some construction has already started in fiscal year 1991. That was the magnet development laboratory. But, yes, the major construction really will not start until late fiscal year 1992 really. And before starting construction, we are still——

Senator CRAIG. You are going to do 2 miles of tunneling——

Mr. MOORE. In late fiscal year 1992.

Senator CRAIG. Your argument again based upon funding delay is—the overall cost is a million dollars a day?

Mr. MOORE. A million a day.

Senator CRAIG. That is in the context of total project ongoing but extended outward——

Mr. MOORE. Yes.

Senator CRAIG [continuing]. Beyond the time frames——

Mr. MOORE. Yes.

Senator CRAIG [continuing]. As you put them together.

Mr. MOORE. Senator, in this report, we recommended a 1-year delay. We came forward, and looking at the ICE report—we agree with the ICE report on that, Mr. Chairman. We looked at this thing. We looked at it. We looked at how fast we had to move to get it done in 1998 as opposed to 1999. And then we looked at the funding problems facing this Congress on top of that. We said that is really unrealistic. So we recommended a 1-year delay.

If we find that there have to be other delays, you are going to hear about it first from us. We think that is our responsibility to this Congress, is to report to you. I intend to do it quarterly on how we are doing on this baseline report to date. Are we one schedule, ahead, or behind, and how much, and how we are doing funding wise? We have never done that before. But we owe that to you, because I have the same concerns both of you do—that this is a massive project that must be run right. There is no room for error in terms of squandering money at this level. You cannot do it.

We will provide the report on SSC funding for the period fiscal year 1988 through fiscal year 1990 within the next few weeks, as well as the report on the first quarter of fiscal year 1991.

And so we intend to give you a report very soon on how we have done through fiscal year 1990. That is 4 fiscal years—1988, 1989, 1990—3 fiscal years. And then we intend to get FY 1991 and give that to you on a quarterly basis and continue doing that right on down the line.

And if we come up against something. If our scientists run up against a problem that a magnet is not going to be ready or something of that nature, we will be the first one to come in and tell you that, report that to you early on. This is going to mean a delay and increase in cost and whatever.

But right now we have every confidence. We can live to this scheduling, cost, and building baseline. And we are doing it. And we have made some very difficult decisions already and we are living up to it.

Senator CRAIG. Mr. Chairman, I have checked most of my questions off. I turn it back to you.

Senator FORD. Well, you know, there are just so many things. And you get so many conflicting statements—GAO, CRS.

Senator CRAIG. Mr. Chairman, when it comes to GAO studies, I have given up on them.

Senator FORD. Well, I understand, but you know——

Senator CRAIG. Their credibility is pretty much down the tubes with me.

Senator FORD. I understand that. That is yours, and I have not liked it for a long time. Now, you are just realizing they are bad. You use it when it helps you, and you damn it when it does not. I have done that a lot of times.

Senator CRAIG. No, I look at who requested the study first and the parameters of the study, and when I see the creator or the instructor of the study saying, well, here is kind of what we would like to find, why do you not find it? I have seen that over the case—not in this one. I have not looked at it yet. You and I both know that is somewhat the case.

Senator FORD. I understand. That is like line item B—it is all right for your president, but not for ours.

Senator CRAIG. No, mine is a generic attack.

Senator FORD. Yes, I understand. I understand. I understand all that.

Mr. MOORE. Senator, if I could—that GAO report is part of a trend that really causes us a lot of trouble on the executive side.

Senator FORD. Well, I did not ask for it.

Mr. MOORE. I know, but we were not given a chance to even comment on it. First time we see it is today.

Senator FORD. That is right. It was the first time I saw it today, too, but——

Senator CRAIG. I have not even seen it yet, and I am going to question it.

Mr. MOORE. You did not miss anything.

[Laughter.]

Mr. MOORE. The point is Congress is increasingly giving direction to GAO, do not let the agency comment on this report. That is a one-sided view. That is a pretty poor way to arm the Congress to make a decision. That is what happened here—that we can answer everything in there and answer it to the way that I think that you would like to see the other side of the issue.

Senator FORD. There are only two items outside of the information we get from your agency and from Dr. Bromley was that the CRS had said that the human genome was a mega project. And I just pointed that out. That is the only thing I said out of that. Then I asked you the question that the GAO had in there as it related to the compressed time for developing the magnets. Now, if that is out of order, I have been out of order for a long time.

Mr. MOORE. No, that is not out of order, Mr. Chairman.

Senator FORD. I have got lots of things that are on my mind. I have to make a decision. I have to vote. And I am worried about the magnets and I am worried about foreign commitment as to the latest date they can commit. We continue to fund even without a commitment.

And so there are just lots of things that bother this Senator and I intend to say it in my feeble way and try to fuss and fume about it until maybe you go back and look at it again. And maybe there is something about worrying about the magnets and getting them completed and on the way before you start doing lots of other things.

You do not even have a fire drill for the tunnel yet as it relates to danger and that sort of thing down there. I have gotten into some nitty-gritty. I understand construction management very well. I started one in 1972 for the government. I think it has been able to save money and you get the right kind of construction management team in. And so I have no fault with it.

So I thank both of you for being here today, but Dr. Bromley I wish you would go back home and pray just a little bit and see if you could not find somebody to tell you to give me your priorities, because you have left me with nothing. They are all good and they are all priorities, and they all ought to be funded.

Well, I have got to make a decision which one is which. And you are the genius here, not me. You are the fellow that has all of the background, and that is the reason you have been selected and that is the reason you are testifying. Somewhere in your judgment there

ought to be priorities, and if you only had x number of dollars to spend, where would you spend them?

And so that is what I have. I have x number of dollars. We have got a fiscal conservative here. And he has x number of dollars to spend. And he has to make a judgment on where the money is spent. I hope he is like I am in that we want whatever judgment we can get from the best minds available.

And so would you reconsider that position? And if out of the goodness of your heart and mind, you would be able to give me your priority, I would appreciate it. Would you think about it anyhow?

Dr. BROMLEY. I will certainly think about it, Mr. Chairman. But what I have given you is the administration's position.

Senator FORD. Would you ask the administration? I am sure that you get to the table every once in a while. I do not get there.

Senator CRAIG. Mr. Chairman, you have got a problem here.

Senator FORD. I know I have.

Senator CRAIG. The problem is he is going to give you the administration's position.

Senator FORD. Which is nothing.

Senator CRAIG. No, he is the administration.

Senator FORD. Right, and he gives me no answer when I ask him a question.

Senator CRAIG. I think the obvious is at hand.

Senator FORD. I understand I am not going to get an answer.

Senator CRAIG. That is the obvious.

[Laughter.]

Senator FORD. But I think I am going to press my case.

Senator CRAIG. I mean as it relates to priorities. I am not going to argue with you about pressing your case. I was just sitting here enjoying the obvious.

Senator FORD. Well, it may be obvious to you, my friend, but I think I have right to continue to ask. And if the administration is going to stonewall me, I am going to start chipping away at the bricks.

Senator CRAIG. How well I know you will.

Senator FORD. Even if I have to use my dang head.

But thank you, Doctor, and thank you, Henson. I appreciate both of you being here today.

The next panel is Dr. Lederman, Dr. Bloembergen, and Dr. Fleury.

Dr. Fleury, I am going to let you go first. We will go from left to right.

STATEMENT OF DR. PAUL A. FLEURY, DIRECTOR, PHYSICAL RESEARCH LABORATORY, AT&T BELL LABORATORIES, MURRAY HILL, NJ

Dr. FLEURY. Well, thank you. I expected to be hitting clean-up. So going out of order is——

Senator FORD. Well, we will not let you be clean-up. We will let you be lead-off.

Dr. FLEURY. Well, Mr. Chairman, thank you very much for giving me the opportunity to comment on the proposed supercol-

lider, and on the related issues of funding of basic research in this country.

As both a manager and an active researcher at AT&T Bell Laboratories for over 25 years, and as a volunteer and an elected representative in the American Physical Society, I have gained some perspective on these issues. And I would like to summarize them briefly here.

My written testimony elaborates on these main points. And I request, as have the previous speakers, to have that testimony submitted to the record.

Senator FORD. Without objection, so ordered.

Dr. FLEURY. Today there are two views regarding the funding of research and development in the United States. On the one hand, Members of Congress and the administration look at the nearly $76 billion expenditure proposed for fiscal year 1992 up considerably from last year, and believe that they have treated science very well.

On the other hand, virtually every study over the past half-dozen years, and plenty of testimony in this chamber has expressed the view that our university-based research is in serious trouble, and that we may be in danger of becoming a second-rate country in science and technology.

I believe that both of these views have some validity, to some degree; but that the problem is not so much the level of our national support for research, as it is the distribution of that support.

We are not putting our money where it will do the most good. We are seriously out of balance in our support of research, and in danger, I believe, of destroying the infrastructure in what I would call productive scientific research.

By that I mean that research which, at least in principle, offers the possibility to impact upon the human condition through technology.

Of the several billion dollars proposed for the physical sciences in the 1991 to 1992 time frame, the dominant amounts are associated with the megaprojects. The space station counts against the 1992 budget to the tune of $2.2 billion. The SSC is in for an alarming 120-percent increase to reach $533 million. When added to the DOE and NSF requests for other aspects of support in particle physics, which exceed $700 million, the projection for high-energy physics in 1992 totals $1,245 million.

This will support approximately 5,000 high-energy physicists, over half of whom are theorists. In contrast, less than $440 million has been requested to support the more than 20,000 condensed matter and materials physicists, who epitomize what has been called here "small science."

This figure, incidentally, also includes support for many chemists and other material scientists. In other words, we are spending about three times as much money to support four times fewer people in doing big science than small science.

Our per capita funding in big science is approximately 10 to 12 times larger than in small science. I think we have to ask whether this ratio represents a wise investment. It is easy to show that virtually every health- and wealth-producing technology in today's society has derived from researching small science. Condensed

matter and atomic physics, chemistry, biology, and material science have given us the transistor, the microchip, the laser, the superconductor, genetic engineering plastics, wonder drugs, high-strength alloys, the green revolution—and the list can go on and on, but I am running out of breath.

We have revolutionized communications, travel, agriculture, computing, health care, et cetera. In fact, one aspect alone, material science, counts for a good fraction of nearly $1.4 trillion of our gross national product in those materials-intensive industries.

From this perspective, then, the technology returns on our investment in big science have been small by comparison. That is not to say that such research should not be conducted or funded, but that it must be done in proportion.

We have arrived at our present state of imbalance, I believe, by a process of gradualism. Over the years we have continued to reduce in real terms the per capita support of small science. Until today we have nearly twice as many researchers in these fields, supported by approximately the same amount of constant dollars as we had a decade ago.

The large projects, on the other hand, are not so easily squeezed. They are either built or not built. And as we are seeing with the SSC, in the building they often appreciate dramatically in cost.

Because it is so diverse and dispersed, small science has lacked the single voice with which big science has been able to speak, thus permitting a number of myths to persist: such as the myth of trickle-down technology; the myth of the single intellectual frontier; and the myth of the non-zero-sum gain. These imply that supporting big science is a good economic investment that can be done without hurting small science.

I think we have reached the point where we can no longer afford this mythology.

Despite my foregoing remarks, I am not against high-energy physics, or even against the SSC. I am for a rational balanced policy of support for basic research. In order to restore balance to this support, we must address the painful question of how to set priorities across fields and sub-fields, an issue that has been raised before here.

Physicists have been reluctant to address these issues, partly on the excuse that no one has requested it, and partly on the real reason that there is not a mechanism presently set up within the physics community to do so. Key requests from a congressional committee or two to the National Research Council might help move things along, however.

By way of just concluding, let me remark that the material science community, which is probably as diverse as any community in science or technology anywhere, is already showing the way. From a series of regional meetings around the country last year where hundreds of scientists and engineers from every discipline, specialty, and type of institution expressed their views, a plan called a National Agenda in Material Science and Engineering has emerged.

This community is trying hard to work with Congress and the administration. And a positive response to their efforts by Government would encourage other fields, I believe, to emulate them.

Parenthetically, the price tag for the entire material science and engineering program is about $1 billion—half the projected 1992 expenditure for the space station, and about twice the next installment for the SSC. It would probably fund 30,000 researchers.

In summary, I believe that basic research in physics has proven over the past few decades to be an excellent investment for this country, both intellectually and economically. And that as the leading Nation in the world, we have both the means and the responsibility to support a broad base of scientific research. This includes both individual investigators, and major facilities.

However, when choices have to be made, the first priority must be given to those arenas of small science which have repeatedly proven to provide enormous leverage in generating both new knowledge, and the foundations for technological growth and economic competitiveness. Only after this priority is met, should we consider more megaprojects.

Thank you very much.

[The prepared statement of Dr. Fleury follows:]

PREPARED STATEMENT OF DR. PAUL A. FLEURY, DIRECTOR, PHYSICAL RESEARCH LABORATORY, AT&T BELL LABORATORIES, MURRAY HILL, NJ

I am grateful to you, Senator Ford and, to the members of the Senate Subcommittee on Energy Research and Development, for the opportunity to comment on the proposed superconducting supercollider and on the important related issues of our nation investment in basic research. I speak as one who has been for many years deeply involved in physics as a researcher and manager at AT&T Bell Laboratories and as a volunteer and elected representative in the American Physical Society. My views, however, do not represent those of either of these institutions but rather reflect the perspective of one who has practiced and managed scientific research for over two decades. A brief biography is appended to my written testimony.

Federal Funding of R&D—Feast or Famine?

Today there is a dichotomy of perceptions in this country regarding the federal funding of research and development. On the one hand, members of Congress and the administration look at the R&D expenditure of $75.6B requested for 1992 (an impressive 18% increase over 1991) painfully aware of the caps on overall spending, and believe that they have not only treated science very well indeed, but that they have exhibited no small measure of political courage in doing so. On the other hand, virtually every study—ranging from the rather informal one reported to the AAAS by Dr. Lederman early this year to the much more comprehensive "Brinkman" report ("Physics Through the 1990's") to the NRC in 1986—and plenty of testimony in this chamber have expressed the view that our university based research is in serious trouble and that we are on the way toward becoming a second rate country in both science and technology. Which view is correct?

I do not believe that our government is antiscience or that our university professors are merely saying, "I exist, therefore I am to be funded." It is important to distinguish the reasons why people pursue careers in scientific research from the reasons why the nation should support scientific research. They are not intrinsically in conflict, but they should be understood. Intellectual curiosity, the thrill of discovery, the excitement of understanding for its own sake—these are what drive the scientist. These are also what drive the Shakespearean scholar; yet we are not proposing to spend $75.6B on scholarship in English literature. Rather, both the government and corporate America support scientific research largely because it has proven to be by a wide margin the best investment in our national future we have ever made. Certainly, our scientific leadership contributes to national pride and prestige. Certainly science is among the very greatest adventures of the human mind. But it is the extraordinary leveraging of human productivity through totally new technology and its concomitant generation of new wealth which justifies our substantial support of scientific research. Yet many rightly perceive that the most productive elements of this research are being starved, while the least productive receive even greater federal support. In other words, both of the dichotomous views

are correct. The problem, therefore, is not so much the level or amount of our national support of research as it is the distribution of that support.

We are not putting our money where it will do the most good. We have lost our sense of balance—so much that we have distorted even the intellectual frontiers of scientific inquiry and are now in danger of destroying our infrastructure in what I will call productive scientific research. By productive research I mean that research which at least in principle offers the possibility to impact upon the human condition through technology.

Federal Funding of R&D—The Question of Balance

To gain some sense of the present state of imbalance, consider some numbers. Of the $75.6B, (18% growth) requested in 1992 for federal support of all R&D, $13.3B (8% growth) is for research. This, of course, is for all fields. In the physical sciences, mega projects dominate the figures. The space station—publicly and universally criticized as having little or no scientific justification—counts against the 1992 budget to the tune of $2.2B. The SSC is in for an astounding 120% increase to reach $534M for 1992. In addition, DOE funding for support of other high energy physics weighs in at $664M (13.2% growth); while DOE's own proposal for its Basic Energy Sciences program (all sciences) is up only 0.4% to $714M.

These amounts are impressive, but in themselves offer no real basis for evaluation. We need a few more figures to appreciate how much we are investing in what; and a few more still to understand the returns on those investments. Unfortunately, the field and funding categories in government parlance are not identical to the categories into which professional societies or scientists sort themselves. Fortunately (for my argument) the numbers are so largely out of balance that a few percent here or there makes no difference to my main point. To begin with there are approximately 5000 particle or high energy physicists in the United States; about half of whom are theorists. By contrast there are about 20,000 condensed matter and materials physicists—most of whom are not theorists.

Federal funding for these fields in the 1991-92 time frame breaks down roughly as follows: High energy physics is slated to receive $1,245M in 1992: $47M from NSF; $664M from DOE in support of people and facilities; $534M from DOE for the SSC. Small science (I've added in materials chemistry, polymers, etc. to the CMP and MP amounts just to be conservative) is slated for $440M: $140M from NSF; $220M from DOE in support of people and facilities and $80M from DOE for construction. Therefore, conservatively, on a per capita basis we are investing nearly ten times as much for each "big science" researcher as for each "small science" researcher. On a per experimentalist basis, the disproportion is even greater. The fact that about one-third of the small science researchers are at least partially funded by industry alters this rate only slightly.

Is this ratio of expenditures likely to probe a wise investment of our national resources? The proponents of the status quo will say "Wait and see; our grandfathers (who were really nuclear physicists) gave you the atomic bomb and atomic energy. Maybe we'll do something as spectacular again." Others, like myself, say "Let's look at the record."

It is easy to show that essentially every health and wealth producing new technology in today's society has derived from research in "small science". Well documented examples appear in the volume "Scientific Interfaces and Technological Applications of the 1986 Brinkman report. Research in small science fields like condensed matter and atomic physics, chemistry, biology and materials science, has given us the transistor, the microchip, the laser, the superconductor, genetic engineering, plastics, wonder drugs, high strength alloys, the green revolution—revolutionizing communications, agriculture, travel, computing and health care. In fact one aspect alone—materials science—accounts rather directly for a $1.4 trillion contribution to our GNP (as documented in the 1989 NRC report "Materials Science and Engineering for the 1990's". From this perspective the technology return on our investment in big science has been minuscule by comparison.

This is not to say that such research should not be conducted or funded. To deny our compelling curiosity about the ultimate make-up of subnuclear matter and the cosmos is to deny something deeply romantic and philosophical about the human mind itself. I believe that our national funding priorities have, however, gotten seriously out of balance and that continuing along the paths proposed by the SSC supporters will make matters seriously, perhaps critically worse.

How Did We Get into this Situation?

The issues are complicated, but I believe that our present situation and the dichotomy I mentioned at the beginning arise partly from a lack of understanding by Congress and the public regarding the nature of scientific research and its relation

to the generation of new technology. Contributing to this misunderstanding is what I call the mythology of megaprojects. There are:

1. The myth of "trickle down technology". This is the notion that while pursuing one objective (A) (e.g. the structure of subnuclear matter), you will discover or develop new and valuable results in another (B). Even in those few cases where megaprojects pushing technology did move things along (like large superconducting magnets) big science played the role of a generous, if demanding, customer and the real cost of the technology advance was much greater than if the technology objective itself had been directly pursued. By contrast small science research—on materials and phenomena germane to the human condition—has given us hundred fold returns on our investment across a broad spectrum.

2. The myth of "The Intellectual Frontier". This states that particle physics represents the supreme endeavor for the human mind, and that it is our duty as thinking people to support it at whatever cost. The facts are that this field is but one frontier among several; that as many new ideas and even theoretical methods flow into particle physics from other fields as flow from it; and that prize winning advances—such as those recognized by Nobel prizes—are more often than not associated with these other frontiers. The most challenging of these frontiers are characterized by complexity rather than by highness of energy. Complex materials, chaos, emergent properties, protein folding and others pose challenges to the intellect every bit as formidable as do tests of the standard model in high energy physics.

3. The myth of the "Non zero sum game". The point here is that even if one grants that the SSC and other megaprojects are technologically irrelevant and not intellectually unique because they are funded through a separate channel, they do not detract from the support of other science. If this were ever true, last year's budget agreement has made it patently and demonstrably false today. Indeed, even within the DOE an "SSC dividend" (money saved by not proceeding) could fund Basic Energy Sciences (currently slated for a meager 0.4% increase in '92).

For whatever variety of political and mythological reasons, this country has allowed its substantial investment in R&D (the size of which incidentally reflects the public's overall confidence in its importance) to become increasingly imbalanced toward megaprojects and away from those many areas of small science which have proven that they pay off.

The two largest and most visible examples of this are the proposed SSC and the space station. The SSC is not to be regarded in the same light as the space station for at least one important reason. In contrast to the space station, the SSC is designed to address scientific questions. I leave the space station for others to consider. The debate on the SSC property centers around two related issues.

1. Are the potential payoffs in terms of new knowledge, new technology, competitiveness, benefit, education, etc. in balance with those to be reasonably expected from other scientific research especially small science?

2. Is the SSC the most effective means to address even its own scientific goals, in terms of design, time scale, cost, and other approaches in either collaboration or competition with other nations?

While I believe there are serious questions surrounding the second issue, I am not an accelerator physicist and have no public position on it. However I hope my testimony has shown that the answer to the first question is a resounding "NO".

What Should Be Done?

In spite of the foregoing remarks, I am not against research in high energy physics, or even against the SSC. Rather, I am for a rational and balanced policy underlying the support of basic research in the United States. My remarks above clearly demonstrate that, viewed as an investment in new technology, education and economic productivity, our national priorities have become seriously out of balance and promise to become more so. Meanwhile our European and Japanese counterparts increase their support for productive scientific research.

We must devise mechanisms to ensure a better balance in our research support so as to provide a greater return on the investment it represents. In the long term we must address the painful question of how to set priorities across fields and subfields. Although demonstrably capable of setting priorities within subfields (witness the clear identification of the SSC as the top priority for high energy physics), physicists have been reluctant to address the cross subfield issues. This reluctance has been excused partly on the grounds that no one has really called for such prioritization and that no mechanism for addressing it now exists within the physics community.

Requests from a key committee or two of Congress through the National Research Council could help alleviate the former, but physicists themselves must get to work on the latter. Encouraging signs that scientists and engineers can come to grips

with prioritization are already coming from the Materials Science and Engineering community. Using the 1989 NRC study "Materials Science and Engineering for the 1990's" as a basis, they convened a number of regional meetings last year to evolve a prioritized plan for implementing the recommendations of this study for the national good. Hundreds of scientists and engineers from every discipline, specialty and type of institution participated. All views were heard, but not all could prevail.

A plan called "A National Agenda in Materials Science and Engineering" emerged. It places emphasis on six specific areas (distilled from hundreds of possibilities) and calls for establishment of a strategic, goal-oriented planning process for the future. This community is trying hard to work with Congress and the administration. A positive response to their efforts by government would surely encourage other fields to emulate them. Parenthetically the price tag for the totality of the MSE program is about $1B, half the '92 projection for the space station, and about twice the '92 installment for the SSC.

In summary, I believe that basic research in physics has proven over the past several decades to be an excellent investment for the United States both intellectually and economically—that as the leading nation in the world we have both the means and the responsibility to support a broad base of scientific research which includes both individual investigators and major facilities. However, when choices must be made among the many alternatives, the first priority must be given to those arenas of small science which have repeatedly proven to provide unparalleled leverage in generating both new knowledge and the foundations for both technological growth ad economic competitiveness. Only after this priority is met should we consider more megaprojects like the SSC.

Prepared Statement of the American Physical Society Council

To assure that the United States can educate an adequate supply of professional scientists and to provide the scientific underpinnings for a sound technological foundation, it is imperative that scientific research be broadly based. The rising cost of front-line research and the creation of promising new fields of physics has, during the last decade, rendered inadequate the support for broadly based physics research. Reversing this trend and strengthening the support for individual investigators must have the highest priority; it is essential to the scientific and technological future of the Nation.

A vigorous research program is composed of both a broad base and major research facilities, such as the Superconducting Super Collider (SSC). The SSC will probe fundamental questions about the nature of matter and allow for the United States to remain at the forefront of elementary particle physics. The SSC should be built in a timely fashion, but the funding required to achieve this goal must not be at the expense of the broadly based scientific research program of the United States.

Condensed Matter and Materials Physics—It's Importance, Opportunities and Challenges

Division of Condensed Matter Physics, American Physical Society, 1990

[A distillation of the report of the Strategic Planning Committee of the Division of Condensed Matter Physics titled "Opportunities, Resources and Problems in the Field of Condensed Matter Physics," 1990]

Science in general and condensed matter or materials physics in particular are of vital importance to any nation which hopes to play a leading, competitive role in today's world. The significance of materials science and engineering for the economic health of this country has been amply demonstrated in a recent survey, "Materials Science and Engineering in the '90's." Eight key industries highlighted in that report account for 1.4 trillion dollars in direct sales in the United States. Of these, aerospace, electronics, telecommunications, and energy account for more than half of this total and are directly dependent upon discoveries in materials physics. Materials physics alone is arguably responsible for the very existence of the electronics industry and for most of the new technologies in the telecommunications and computer industries. Expanding beyond the electronics industry, optical fiber and the miniature semiconductor laser physics discoveries and developments are rapidly bringing about the photonic age. Superconducting magnets have made Magnetic Resonance Imaging (MRI) a practical and powerful tool for sophisticated medical diagnostics. Composite materials with extraordinary strength and other useful properties are being used in construction, transportation, medicine, and sports. The

recent discoveries of superconductivity in oxide materials eventually may offer contributions to the economy which could rival those of the laser and transistor. Because of its central role in the world economy, materials science which embraces materials physics as its scientific basis is recognized to be of major strategic importance.

Yet the continuing health of materials physics research in the United States is in serious jeopardy.

In addition to the economic and technological importance of the field; materials physics continues to be at the forefront of intellectual and educational challenge. Within the past five years alone, three Nobel Prizes have been awarded for research in materials physics (the quantum Hall effect, the scanning, tunnelling microscope, and high temperature superconductivity). Seven of the last twenty prizes went for research related to this field. And together with other "small science" fields such as chemistry, atomic and molecular physics, materials physics has produced more than two-thirds of the physical science PhD's in the United States. "Small science" in general and materials physics in particular are vital components in the training and education of the nation's technical work force.

Yet the future supply of engineers and scientists in materials physics in this country is in jeopardy.

Responding to a growing sense of crisis within the materials physics community, the Division of Condensed Matter Physics, representing nearly a quarter of all division members of the American Physical Society, has recently completed a study of the opportunities, demographics and support related to this field. It has found a clear picture dominated by two strongly opposing trends.

On the one hand, the field of materials physics is found to be vital and rapidly growing by a variety of measures. The demand for new faculty at universities, the increase in graduate students wishing to enter this field, the rate of scientific publications, the size and number of contributions at related professional meetings, all point to an approximate doubling of the activities in this field since 1980. Approximately one-third of the nation's physicists work in materials physics today. Correspondingly, about 15% of the nation's materials scientists and engineers are physicists. Overall, approximately 20,000 physicists are at work in the United States in the general field of materials. The report details the trends and demographics of the field.

On the other hand, the report found an opposing and deeply disturbing trend. The funding for materials physics has not been remotely commensurate with the growth of the materials physics community. As a result, many vital and productive research programs have begun to suffer, and students are now being turned away from this most important field. Despite the large increase in real terms of the nation's expenditure for overall scientific research and development, materials physics and other "small science" fields have actually experienced a decrease in funding. Non-defense spending for materials science has remained essentially flat during the decade of the '80's. This inability of federal support to keep up with scientific and technological opportunities is particularly severe for the individual investigator on the university campus, the very mode which has traditionally produced so much new science and technology, and which educates our scientific and engineering work force.

Our report has shown in detail where the problems lie in the funding of "small science" as manifested in materials physics. Between 1985 and 1989 the overall National Science Foundation (NSF) budget increased by more than 25%. But the Division of Materials Research (DMR) which carries the major responsibility for materials and condensed matter physics, increased by only 7% in current dollars. When corrected for inflation, the support for materials physics has actually decreased. Young researchers have been particularly hard hit. The success rate for proposals in DMR has dropped from over 40% to below 25%. The situation is not much different for Department of Energy support of research. Laboratory research funding decreased from $68 million to $62 million over the period from '82 to '90; increases were in the construction of large facilities. Defense funding for basic materials research has essentially remained flat over the period of the '80's with a one-time peak in 1986. As a fraction of the overall Department of Defense budget for research and development, basic research has fallen continuously for more than twenty years. The decoupling of the basic research community from the defense establishment which began in the '70's continues unabated today. In brief, the crisis in "small science" funding on our university campuses is widely based and shows no sign of turnaround.

In summary, condensed matter or materials physics has been a vital field both intellectually and educationally for over forty year. It is the source of many major

technologies with a trillion dollar impact on our national economy. During the decade of the '80's, materials physics activities have effectively doubled in size and scope. Over the same period, however, federal funding for materials physics, and indeed for all of "small science," has decreased in real terms. Funding of university research has dramatically lagged the growth. Federal support for materials physics research must focus anew on individual investigator support if we are not to jeopardize irreparably the sources of our future technological competitiveness and intellectual leadership on the world scene.

Senator FORD. Thank you, Doctor.

Dr. Bloembergen.

STATEMENT OF DR. NICOLAAS BLOEMBERGEN, PRESIDENT, AMERICAN PHYSICAL SOCIETY

Dr. BLOEMBERGEN. Mr. Chairman, thank you.

I appreciate the opportunity to appear before you today to discuss the concerns of the American Physical Society regarding priorities for the funding of physics. And I hope that the written testimony will become part of the record.

Senator FORD. It will be included in the record, you may highlight your statement.

Dr. BLOEMBERGEN. The 93-year old American Physical Society is the world's premier association of physicists. It has over 41,000 members in academic, Government, and industrial laboratories. It is dedicated to the advancement and effusion of the knowledge of physics.

In January of this year the elected council of the American Physical Society took the unprecedented step of issuing two statements on priorities in science funding, attachments A and B of the written material submitted.

In the first of these statements, the council gave the highest priority for funding to support individual investigators. The council also urged construction of the superconducting supercollider in a timely fashion.

But the council cautioned that the SSC must not be built at the expense of the broadly based scientific research program of the United States.

In a second statement, the APS council concluded that scientific justification does not exist for a permanently manned space station.

Major new initiatives, such as the superconducting supercollider and the Space Station Freedom serve as conspicuous reminders of the commitment of the United States to science and technology. Such symbols are not without practical benefits. It would be tragic, however, if we were to retain only these symbols of leadership, while scientific activities that more directly affect our lives are permitted to wither.

From high temperature superconductivity, to growth hormones, to the chemical reactions that devour the ozone, the discoveries that are changing our lives are most often made by individual scientists or small group. And their plight is increasingly becoming desperate. Moreover, most of the new scientists that enter our work force are trained on these small science projects.

I feel at this stage I must comment on a statement made by Secretary Moore earlier this afternoon. He enumerated a list of spin-

offs of the SSC. And he included superconducting magnets and magnetic resonance imaging.

As one of the pioneers in the field of magnetic resonance, I can assure you that these are spinoffs of small-scale science, and not of the SSC.

Attribution to the SSC of the other spinoffs mentioned are also highly questionable.

The APS position on the SSC is entirely consistent with the policy endorsed by two administrations: that the SSC must be built with new money, not at the expense of other scientific programs. Indeed, even the leaders of the high-energy physics community have stated that without new money, the SSC should not be built.

When those assurances were issued, however, no one anticipated the current budget crisis. The budget agreement reached last fall appears to ensure that there will be no new money.

What is the problem? The supercollider and the Space Station Freedom were singled out in the APS statements because of their extraordinary cost. Even as the projected cost of these megaprojects has risen, the crisis in individual investigative funding has worsened, with little prospect for early relief.

We recognize the concerns that led Congress and the administration to agree on the budget plan that caps domestic discretionary spending. But science is particularly vulnerable to such a cap, since research funding is entirely discretionary. Indeed, R&D makes up nearly 30 percent of the total discretionary budget, and 32 percent of the outlays.

In such a funding environment, major new initiatives, whose annual costs are projected to escalate for several years, threaten the already precarious house of Government-funded research.

It is important to understand the roots of the current crisis in Government-funded science. Congress, after all, has been consistently supportive of science, even in these difficult times. And scientists are very grateful for that support.

But the world has experienced an explosive growth in scientific knowledge. There are whole new fields of science, such as gene mapping, and high-temperature superconductivity, that did not even exist a decade ago. The result is that although science funding has grown, it is spread more thinly every year. We have become the victims of our own success.

A recent study by the Office of Technology Policy appears to suggest that since science funding has consistently risen faster than the cost of living, there is not really a funding problem. Instead, the problem must be too many scientists.

Such a conclusion is unwarranted. Previous studies have come to the opposite conclusion. I do not know how many scientists the United States needs or will need 10 years from now. I do not believe anyone does. But it is a competitive and increasingly technological world. And any Nation that restricts the growth of science to the inflation rate will quickly be out of the race. Once out, it may be very difficult to get back in.

The Office of Technology assessment, the OTA report, does point out, however, that if currently planned megaprojects, including the earth observing satellites, the human genome project, Space Station Freedom, and the supercollider are included in the 3 percent

growth rate projected for science, funding for the science base will remain flat throughout the 1990's. And this will not sustain our position in broad-based science in the world.

What should be done? The existing budget constraints make attempting to adopt compromises which would, in our opinion, do more harm than good to the scientific enterprise. The American Physical Society is on the record that under no circumstances should SSC funding come at the expense of the funding for broad-based, individual investor programs. Such research programs are essential to maintain broad-based, United States leadership in science and technology.

The construction phase of SSC should probably not be stretched out by more than 25 percent. The primary goal of the SSC is to restore leadership for the United States in high energy physics.

If the program was stretched out by, say 50 percent, the total cost will go up, and we may still lose the race with CERN's next program. In a large project like this, there should be ample cushion for contingencies. The worst possible outcome would be to build a costly facility that will not work as planned.

Now if Congress decides that it is willing to proceed with the SSC but under the above-mentioned conditions, in addition to the existing budget constraints, it is our clear recommendation that the necessary additional funds be found by cutbacks, stretch-outs, or even elimination of the manned space station program.

This would not constitute a serious set-back for science.

Thank you.

[The prepared statement of Dr. Bloembergen follows:]

PREPARED STATEMENT OF DR. NICOLAAS BLOEMBERGEN, PRESIDENT, AMERICAN PHYSICAL SOCIETY

Mr. Chairman and Members of the Committee: I appreciate the opportunity to appear before you today to discuss the concerns of the American Physical Society regarding priorities for the funding of physics. The 93-year-old American Physical Society is the world's premier association of physicists, with over 41,000 members in academic, government and industrial laboratories. It is dedicated to the advancement and diffusion of the knowledge of physics. Our principal activities involve the exchange of new scientific results through the publication of scientific journals and the organization of scientific conferences.

In January of this year, the elected Council of the American Physical Society took the unprecedented step of issuing two statements on priorities in science funding (attachments A & B). In the first of these statements, the Council gave the highest priority for funding to support for individual investigators. The Council also urged construction of the Superconducting Supercollider in a timely fashion, but the Council cautioned that the SSC must not be built at the expense of the broadly-based scientific research program of the United States. In its second statement, the APS Council concluded that scientific justification does not exist for a permanently manned space station.

Major new initiatives, such as the Superconducting Supercollider (SSC) and Space Station Freedom (SSF), serve as conspicuous reminders of the commitment of the United States to science and technology. Such symbols are not without practical benefits. It would be tragic, however, if we were to retain these symbols of leadership, while scientific activities that more directly affect our lives are permitted to wither. From high-temperature superconductivity to growth hormones to the chemical reactions that devour the ozone, the discoveries that are changing our lives are most often made by individual scientists or small groups, and their plight is increasingly desperate. Moreover, most of the new scientists that enter our work force are trained on these "small science" projects.

The APS position on the SSC is entirely consistent with the policy, endorsed by two administrations, that the SSC must be built with "new money"—not at the expense of other scientific programs. Indeed, even the leaders of the high-energy phys-

ics community have stated that without new money, the SSC should not be built. When those assurances were issued, however, no one anticipated the current budget crisis. The budget agreement reached last fall appears to ensure that there will be no "new" money.

What is the Problem?

The Super Collider and Space Station Freedom were singled out in the APS statements because of their extraordinary cost. Even as the projected cost of these mega-projects has risen, the crisis in individual investigator funding has worsened, with little prospect for early relief. We recognize the concerns that led Congress and the Administration to agree on a budget plan that caps domestic discretionary spending, but science is particularly vulnerable to such a cap, since research funding is entirely discretionary. Indeed, R&D makes up nearly 13% of the total discretionary budget and 22% of the outlays. In such a funding environment, major new initiatives, whose annual costs are projected to escalate for several years, threaten the already precarious health of government-funded research.

It is important to understand the roots of the current crisis in government-funded science. Congress, after all, has been consistently supportive of science even in these difficult times, and scientists are grateful for that support. But the world is experiencing an explosive growth in scientific knowledge. There are whole new fields of science, such as gene mapping and high-temperature superconductivity, that did not even exist a decade ago. The result is that, although science funding has grown, it is spread more thinly each year. We have become the victims of our own success.

A recent study by the Office of Technology Policy appears to suggest that, since science funding has consistently risen faster than the cost of living, there is not really a funding problem; instead, the problem must be too many scientists. Such a conclusion is unwarranted; previous studies have come to the opposite conclusion. I do not know how many scientists the United States needs. I don't believe anyone does. But it is a competitive and increasingly technological world, and any nation that restricts the growth of science to the inflation rate will quickly be out of the race. Once out, it may be difficult to get back in.

The OTA report does point out, however, that if currently planned mega-projects, including the Earth Observing Satellites, the Human Genome Project, Space Station Freedom, and the Supercollider, are included in the 3% growth rate projected for science, funding for the science base will remain flat throughout the '90s. That will not sustain our position in the world.

How Did We Get Here?

Prior to 1983, the United States owned high energy physics. Americans made virtually every major discovery and won nearly every major prize. Europe, however, was determined to regain some measure of the scientific dominance it enjoyed prior to World War II—at least in part to stem the "brain-drain" to the United States. The Europeans joined forces to build CERN, the European Center for Nuclear Research, in Geneva. American scientists were invited to participate in research at CERN, but the key problems seem to have been reserved for Europeans.

In 1983, the three bosons that transmit the weak force, the W+ the W- and the Z-zero, were discovered at CERN. The United States, which was building the Isabel accelerator on Long Island to search for these very particles, had stumbled for the first time. Isabel was over budget and behind schedule. The decision was made to cut our loses: Isabel was abandoned; its gloomy tunnel is a reminder of the price of coming in second. Even the New York Times, in an editorial, called for "revenge." The lessons of Isabel should be kept in mind.

Progress in high-energy physics is constrained by the energy to which sub-atomic particles can be accelerated; the energy must continue to increase, or the field will stagnate. The size and cost of accelerators rises with the energy. It is believed that the Supercollider will lead to the discovery of the origin of mass. That is an awesome goal. It seems almost unthinkable that humankind would stop now with the goal almost in hand. The question is when that goal will be reached—and by whom.

What Should Be Done?

The existing budget constraints make it tempting to adopt compromises which would in our opinion do more harm than good to the scientific enterprise.

1. The American Physical Society is on record that under no circumstances should SSC funding come at the expense of funding for broad based individual investigator programs. Such research programs are essential to maintain broad-based U.S. leadership in science and technology.

2. Congress must resolve its ambivalence with regard to foreign participation in the SSC. The current plan calls for $1.6 billion of the SSC cost to come from foreign

partners. At present, however, foreign commitments amount to less than 3% of that figure. At times, Congress appears to be urging the DOE to recruit foreign partners, while at other times it cautions against making them "real" partners. It is no secret that CERN is attempting to recruit the same countries for its proposed Large Hadron Collider, which is intended to compete with the SSC.

3. The construction phase of the SSC should not be stretched out by more than 25 percent. A primary goal of the SSC is to restore leadership for the United States in high-energy physics. If the program were to be stretched out by, say, 50 percent, the total cost will go up, and we may still lose the race with CERN's next program.

4. There should be ample cushion for contingencies. The worst possible outcome would be to build a costly facility that would not work as planned.

5. If Congress decides that it is willing to proceed with the SSC under the above-mentioned conditions in addition to the existing budget constraints, it is our clear recommendation that the necessary additional funds be found by cutbacks, stretch-outs, or even elimination of the manned space station program. This would not constitute a serious setback for science.

[Attachment A]

AMERICAN PHYSICAL SOCIETY COUNCIL STATEMENT ON PHYSICS FUNDING AND THE SSC

To assure that the United States can educate an adequate supply of professional scientists and to provide the scientific underpinnings for a sound technological foundation, it is imperative that scientific research be broadly based. The rising cost of front-line research and the creation of promising new fields of physics has, during the last decade, rendered inadequate the support for broadly based physics research. Reversing this trend and strengthening the support for individual investigators must have the highest priority; it is essential to the scientific and technological future of the Nation.

A vigorous research program is composed of both a broad base and major research facilities, such as the Superconducting Super Collider (SSC). The SSC will probe fundamental questions about the nature of matter and allow for the United States to remain at the forefront of elementary particle physics. The SSC should be built in a timely fashion, but the funding required to achieve this goal must not be at the expense of the broadly based scientific research program of the United States.

[Attachment B]

AMERICAN PHYSICAL SOCIETY COUNCIL STATEMENT ON THE MANNED SPACE STATION

PREAMBLE

The Council of the American Physical Society is concerned that there remains widespread public and governmental misunderstanding of the justification for the Manned Space Station. After a review of the experimental program proposed for the Space Station, the Council is issuing the following statement.

STATEMENT

It is the view of the Council of the American Physical Society that scientific justification is lacking for a permanently manned space station in earth orbit. We are concerned that the potential contributions of a manned space station to the physical sciences have been greatly overstated and that many of the scientific objectives currently planned for the space station could be accomplished more effectively and at a much lower cost on Earth, on unmanned robotic platforms, or on the shuttle.

The United States needs a vigorous space science program, but such a program can be implemented for the foreseeable future without the proposed manned space station.

Senator FORD. Thank you very much.
Dr. Lederman.

STATEMENT OF DR. LEON M. LEDERMAN, DIRECTOR EMERITUS, FERMI NATIONAL ACCELERATOR LABORATORY, BATAVIA, IL

Dr. LEDERMAN. Thank you very much, Mr. Chairman. And it is a pleasure to be back here again.

Senator FORD. Yes, it is good to see you.

Dr. LEDERMAN. And again, I will also abbreviate my remarks.

Senator FORD. Without objection, your full statement will be included in the record.

Dr. LEDERMAN. I feel like my whole life was poisoned in Little League when I came up at bat, with the bases loaded, and struck out. And here I am, in the same situation.

I would like to stress several points relevant to the hearings. And I will skip over the ones that have been covered amply.

I essentially agree with everything that everybody has said here today, more or less—sometimes more, sometimes less. A few words about the scientific drive for the SSC——

Senator FORD. That is almost the kind of answer I got from Dr. Bromley.

[Laughter.]

Dr. LEDERMAN. I guess I have a long association with the SSC, I probably initiated the discussions within the high-energy community which led to the proposal. So I am really a culprit.

On the other hand, I have been very, very concerned about the individual investigator, as my colleagues probably know, and agree with them fully on how important that is. So I have a hard job to straddle.

I would like to talk a little bit about the cost estimates, things that have not been brought up, a little bit about foreign participation—although that was pretty well covered—and then this crucial and contentious issue of big science versus little science and the health of the research establishment.

As the chairman started, the SSC is an enormous project for basic research. It has been compared by some reporter to the pyramids. And I do not know who designed the pyramids, but I understand my ancestors did most of the work.

It has really resulted from a confluence of three events: one was a realization of a scientific enigma that could only be solved by going to this new energy domain; the other was the success of our colleagues we love to hate at CERN, with their pioneering proton-anti-proton collider, a device which one could not have anticipated would be successful, but was brilliantly successful; and Fermilab's success in constructing a large array of superconducting magnets and conquering the wire and intricate wire technology in the years 1972 to 1979.

We are in what I would call the fifth phase. I have lived through, in my vast experience, four generations of new frontiers in the energy domain. First, as a graduate student I watched President Eisenhower—the President of Columbia University at the time—initiate the highest energy accelerator at 400 million volts for 1950. And he opened the door on a new domain of sub-nuclear research: properties of meson, strong forces, and the entire field of broken symmetries emerged from that.

The next generation, the billion-volt range, 1955, taught us about anti-matter, and about a complex and astonishing zoo of new particles produced in collisions. So many were found we were in danger of depleting the Greek alphabet, which is our usual source of names for these particles. In this period there was a worldwide entry into the field, machines and villages near Tokyo and Moscow, and Geneva, and Hamburg, New York, and San Francisco.

In the next phase, 1960's, tens of billions of volts taught us to see these primordial building blocks of the universe, the quarks and leptons—if you can remember the Morse Code with its dots and dashes, you put them together to make the letters, you put the letters together to make the words, you put the words together to make all the books in the library. It is kind of a metaphor for the universe. The dots and dashes of the Morse Code are the zeros and the ones, for younger people, are the primordial elements of that kind of metaphor. We think we have the zeros and the ones. They cannot be divided any more.

And the present generation of machines, the 1980's, exploring the trillion-volt domain, revealed the full shopping list of ingredients which make a universe.

Exciting new development data from the astronomical studies of the birth of the universe, that is a cosmic accelerator with a totally unconstrained budget, made use of the emerging picture of particles and forces in order to understand that situation. And in turn, contributed early universe data to this standard model of particle physics.

It may be encouraging to Congress that whereas all of our previous attempts to go to new energy domains had open-ended possibilities, with the SSC—whereas it may not be the very last accelerator wished for by scientists—now closes a gap between terrestrial experimentation and a great big accelerator in the sky. And it is that closure of the gap which some kid, now in high school hopefully, now will bridge by some theoretical breakthrough.

By the time the SSC comes on the air, the youngest of our accelerator inventory will be some 12 or 15 years old. For the SSC, the interval between its first concept—the gleam in the eye—and when being finally appears, will have been over 20 years.

And since this is a Senate committee, and you are beholden to your constituents, I think if you looked back at the results, the intellectual results, the contributions to culture and things that are hard to quantify, part of that is not so hard. Because people are trained and those people go out into all kinds of fields.

But I think in story after story we can illustrate that the cost of these machines is largely paid for by these spin-offs that have been alluded to from time to time. This is not the reason for building the SSC. It would be totally stupid to propose an SSC because of spinoff benefits. But there are spinoff benefits. They always come, for any project, as was mentioned before. And these essentially pay back to the treasury, and GNP-generated, and quality of life in many ways. And I could regale you with such stories.

Let me skip to cost estimates. I have only the following to say—it has been—the chairman mentioned this himself. I followed the cost estimates from the earliest meetings. And the first cost estimates for the accelerator carried out at Cornell in 1983, came to $2.7 billion. That was a cost estimate for the accelerator that tunneled everything you needed to build the accelerator.

Today the cost estimate is $8 billion. But that $8 billion has a new ethic, which Congress rightfully demands. They want to know the total cost. They do not want to know the cost of the accelerator. And traditionally, as we grew up in this field, it was always the cost of the accelerator that Congress had a vote on. And then later

you found out it needed equipment, yes, it needed this, it needed that. There was inflation, and so on.

And the $8 billion, as far as I can tell—without having studied in detail—has all of these ingredients. Now if you take the $2.7 billion and you escalate to the 1990 numbers we are talking about, it comes out $4 billion, which is very close to the machine costs now being estimated. So the cost has not doubled and tripled and so on. It is misleading. It has gone up about 40 percent. And it has gone up 40 percent between the people who were sitting in a tower in Berkeley and designing an in-principle machine, and the people who were going to build the machine, in Texas, with a specific site, and with certain amount of conservatism.

It is a lot of money. But I am saying it is not a community that has been excessively sloppy in this. It has been, in fact, remarkable that the price of the machine has held over such a long period of time.

And I have a few comments on international collaboration. I confess there is some frustration that it is going so slowly, because 4 or 5 years ago we were talking to our colleagues around the world and getting a lot of reactions and getting a lot of interest in this field. And so it is a frustrating thing. But it is an issue which is certainly above my salary level.

Except to point out—let me take the case of India, that I know something about, because I helped negotiate that in a sense, informally—if India contributes, in kind, $50 million, which is stuff that they make in their own shops, it will save the American taxpayer $200 million, largely because their salaries are so low that you get that benefit of a factor of something like 4 or 5 in savings. And so I have been pushing very hard on countries like India. Korea is a good example, Brazil—there are many countries we can go after who will benefit.

And that is another issue that came up in the meeting—they will benefit because in the process of making something for the SSC, and making something that is going to be on a world stage, they will push their own technology very hard. And that is a benefit to them. That is one of the reasons they gain.

My final remark has to do with just this issue that was raised, and I think it is useful to raise it again. The point has been made over and over again—and as I spent the years 1984 or so to 1989 on the road selling the SSC, by giving talks all over the place, I always said, this must come from new money. This cannot come out of a fixed science budget because it is too large a project.

And it is ever clear now that science in the United States, basic research, applied research as carried out in universities, is under terrific stress. There has to be some kind of a reasonable balance between big science—I do not like that word. What it really is is shared facilities.

Many, many years ago, when I was a graduate student, there were 20 frontier laboratories that did high-energy physics in 20 universities. Today there are two major facilities in this country, and two small ones. And no doubt, as we go on, it will be reduced.

What happens is the same as with large telescopes, with space observatories, with oceanographic vessels, the genome biologists, the material scientists who need synchrotron light sources, we need

large facilities to carry on research. And we need individual investigators who are fortunate and clever enough to do their research on tabletops in the university. We have to find the right balance.

And the stresses that you hear about, seem to me come from the fact that this Nation in 1991, in spite of the impressive increases that have been voted in two administrations—proposed by administrations, voted by Congress—is still underinvesting in science—a statement that echoes a large number of people: Eric Bloch, Allan Bromley, Frank Press—and many in Congress who recognize that it is going to be difficult to get from where we are now, to where, probably, there is a better balance in the priorities of the Federal Government's budget of $1.5 trillion between the kind of science we are talking about now, which would relax this tension, and allow us to do both kinds of science: the science of shared facilities and the science of the individual investigator.

Thank you.

[The prepared statement of Dr. Lederman follows:]

PREPARED STATEMENT OF DR. LEON M. LEDERMAN, DIRECTOR EMERITUS, FERMI NATIONAL ACCELERATOR LABORATORY, BATAVIA, IL

Mr. Chairman: It is a pleasure to testify before this committee again. The issue is the Supercollider. I have a long history of association with this concept. I may have been the first to initiate the discussions in 1982 which eventually lead the particle physics community to endorse the SSC as its first priority. In the period of 1983 to 1989, while Director of the Fermilab, I was a prominent advocate of the Supercollider even after the site decision which located the facility in Waxahachee, Texas, instead of in my own state of Illinois.

Since then, I have been a member of the Laboratory Science Policy Committee and of the URA Board of Trustees.

In my comments, I would like to stress four points which are relevant to today's hearing.

These are: (1) the scientific drive for the SSC, (2) alternatives to the SSC, (3) the present cost estimates, schedule and technical difficulties, (4) the question of foreign participation, (5) the importance of the SSC in the context of the health of scientific research in the United States, including the contentious issue of big science vs small science.

I. THE SCIENTIFIC MOTIVATION FOR THE SSC, REVISITED IN 1991

Discussions of a next step beyond Fermilab's Tevatron have been going on since 1978. These achieved a renewed fervor since 1982, stimulated by the CEO success with colliding beams of protons and antiprotons and Fermilab's successful mastery of superconducting magnet technology. These encouragements fortified the scientific drive for exploring a new energy frontier, twenty times higher than Fermilab, which is the world leader today.

In my forty years of experience, I have witnessed the birth of some four generations of new frontiers in the energy domain. Some have been strongly motivated by scientific puzzles which demanded more incisive measurements at higher energies and some had more diffuse motivations on the general thesis that higher energy usually leads to new discoveries and new insights. When President Eisenhower (of Columbia University) cut the ribbon on the 400 million volt Nevis Cyclotron, initiating the highest energy particle accelerator of 1950, he opened the door to a new domain of subnuclear research involving the properties of mesons, strong nuclear forces and the entire field of broken symmetries which have continued to prevent us from realizing the complete and, hopefully, beautiful overarching theory of how the physical universe works. (As an input to my later remarks I will point out that in this period there were about 20 particle accelerators on college campuses around that nation.)

The next generation in the billion volt range taught us about antimatter and about a complex and astonishing zoo of new particles produced in the nuclear collisions. So many were found that we were in danger of depleting the Greek alphabet, our usual source of names for new particles. In this period there was a world wide entry into the field with machines in unheard of villages near Tokyo, Moscow,

Geneva, Hamburg, New York ad San Francisco. In the next phase, tens of billions of volts, we began to see what we now believe are the primordial building blocks of the Universe, the quarks and leptons. New accelerator technologies and new detector technologies helped to advance our understanding of matter and the forces that control the coalescence of particles to that which we can see and touch. The present generation of machines, exploring the TeV domain have revealed the full shopping list of ingredients which make a universe.

We believe we have the entire lepton picture and the quark set is missing only one of its six members, the top quark. There is a fair expectation that the top quark will be found at Fermilab within the next two to five years. We have now seen all the force-carrying particles, the W's, Z's, gluons and photons. We have learned how to unify and we have succeeded in unifying the weak and electromagnetic forces. Our appetites for unification and simplification have been thoroughly whetted. In an exciting new development, data from the astronomical studios of the birth of the universe (a cosmic accelerator with an unconstrained budget!) have made use of the emerging picture of particles and forces and have in turn contributed early universe data to the so-called standard model of particle physics.

It turns out that collisions in particle accelerators like the SSC are an infinitesimal replica of the normal behavior of all matter shortly after creation of the universe in the Big Bang. It should be encouraging to the Congress that, whereas the SSC may not be the very last accelerator ever wished for by scientists, it does help to close a gap in our ability to study the microworld, the gap between terrestrial machines and the eat.Accelerator-in-the-Sky.

As early as the late 70's it became clear that the Tevatron Generation (including the LEP machine at CERN, the SLC machine at Stanford, the DESY collider in Hamburg and the UNK machine in Serpuhkov) would be exceedingly unlikely to address the one enigma that confronted all our efforts. Our aspirations are for a Grand Unified Theory which would account for the six quarks and six leptons and would explain how and why we appear to have four forces. Our efforts to unify and to synthesize the deeper order which must be there is teased and frustrated by our ignorance of new phenomena that take place at the next energy frontier—the tens of TeV frontier. In fact, the parameters of the SSC are established by a particular prediction, the possible existence of a mysterious "Higgs" phenomenon. Our theories tell us that something new happen if we can observe with precision in the domain which SSC is designed to illuminate. In the simplest scenario, we will discover the Higgs Boson (which the Mayor of Waxahachee, Texas, has assured us we must do as a leader of nations). Higgs bosons seem to be nature's way of hiding the beauty and simplicity of its laws. Higgs fields give a variety of masses to the quarks, leptons and force carrying W's and Z's. SSC is designed to confront the Higgs theory. In more general scenarios, we will uncover the data we need to unify the forces, we will have created the scientific tool to probe more deeply into the inner space, equivalent to observing the rim of the universe in outer apace. In fact, both sciences, particle physics and cosmology are essentially dependent on instruments like the SSC and the hopefully soon to be repaired Space Telescope.

By the time SSC comes on the air, the youngest of our accelerator inventory will be over 12 to 15 years old. The interval between gleam-in-the-eye and beam-in-the-Lab will have been about 20 years. In the past decade of SSC activity the motivation for exploring this domain has only become stronger. As data from CERN's LEP machine and the TEVATRON come in, the possibilities for discovery in the SSC domain only become more dramatic. I neglected to mention that Congress played a vital role in this brief history—the famed Joint Committee on Atomic Energy questioned, argued, but inevitably supported this adventure which has brought us so close to a complete synthesis. Although science has made enormous strides in all fields from Anthropology to Zoology, it would have been unthinkable not to have pursued this quest for a comprehension of the world in which we find ourselves. And since this is a Senate Committee and you are beholden to your constituents, let me assure you that this quest has pretty much paid for itself. In story after story we can tell of how the study of quarks has generated invention and technology, has generated economic activity and enhanced the well-being of our citizens. We do not propose the SSC because of its societal benefits but if it fails to deliver on this, it will be the first time in history. I have, Mr. Chairman, deleted the many attributes of SSC that are outside of the scientific drive since these have been stated here many times.

II. ALTERNATIVES FOR SSC

The drive to explore the "SSC-domain" is of course shared by physicists the world over. Our colleagues at CERN, the European consortium have proposed to build a "17 FeV" proton-proton collider, using the existing LEP tunnel of 17 mile circumference (LHC). It has been argued that the United States could save a huge sum by collaborating with CERN. As best we can tell, the costs of the two machines, when proper accounting is done, is pretty much in the ratio of the energies. The tunnel savings are more than used up in the higher field magnet technology they must master in order to partially overcome the constraints of the tunnel. My real problem with the CERN approach is that it will still require a huge investment in man-years of creative scientists and engineers as well as resources but with a much reduced guarantee of confronting the crucial scientific issues that motivate both machines.

A careful reexamination of the energy parameters by HEPAP a year ago lead to the conclusion that:

> ". . . any substantial reduction in the energy of the SSC would compromise our ability to elucidate the nature of electroweak symmetry (i.e. Higgs) a truly fundamental problem at the core of the Standard Model."

Since the SSC will be the U.S. machine through the first decades of the 21st century, a constrained collaboration with the Europeans on a much weaker proposal would seem not to serve the needs of science or of the U.S. particle physics community.

III. COST ESTIMATES, TECHNICAL PROBLEMS

Here I can only offer a visceral reaction to the present cost estimate. I believe there is ample contingency in the estimate to cover a host of as yet unforeseen difficulties. This is not a simple machine and the basic culture of machine designers is to devise improvements which will enhance the reliability and performance characteristics. The one concern I have has to do with the performance of industry in the fabrication of superconducting magnets. I believe we have a workable magnet design. There is now a solid core of experience at the collaborating national laboratories in the assembly of these very intricate devices. This knowledge will be transferred to industry at Fermilab and Brookhaven in a plan that seems to have anticipated most contingencies. Still, the record of U.S. industry in carrying out advanced technological manufacture on budget and schedule is not great. I suspect this will require continuous vigilance.

I would like to stress that the cost increases have been greatly exaggerated in the press. The estimated cost of the accelerator has indeed been increased by about 30–40% since the early CDG estimates in 1984. However, the numbers now used are responsive to the Congressional insistence that it know the project cost. This includes inflation, contingency (almost $1 billion), experimental equipment and pre-operating costs. Thus the current estimate of $8.3 billion should not be compared with earlier estimates of $4 billion which applied to the machine alone.

To summarize, I believe that able management can result in a machine which meets the specifications and which can be built in nine or ten years within the budget requested. It is by no means an easy machine and it will require very close monitoring by DOE, by the URA contractors and by the scientific community (HEPAP) to insure that this able management is in place and functioning well.

IV. INTERNATIONAL COLLABORATION

Here I confess to some mystification as to why progress has been so slow. I personally know of intense discussions at the scientist-to-scientist level with colleagues in Japan, Korea, Brazil, India, Italy, Taiwan, Canada, Soviet Union, and Mexico. I was instrumental in obtaining a pledge from then Prime Minister Rajiv Gandhi through his Science Advisor for a $50M contribution of in-kind components for the accelerator. Such a contribution would reduce the costs of U.S. taxpayers by 4 or 5 times that much because of low labor costs in India. Indian engineers are now in residence at SSCL so that it isn't a lost cause.

Enthusiasm for participation and recognition of mutual benefits have come from scientists and science policy officials in all the countries I mentioned. Why we haven't signed these up yet is an enigma unless it is due to the mixed signals that DOE gets from the Congress. In so far as detectors are concerned, the detectors that SSCL is encouraging have strong collaborations from Japan, Soviet Union, UK, France, Italy, Israel, Beijing, Bulgaria, Canada, Rumania and Czeckoslovakia. (Of course if I'm counting, it is not clear how we count the Soviet Union.)

My point is clear. LHC will clearly cut into the support which Europe will give to the machine construction. However, given a vigorous drive by high enough officials, I still believe that we can tie down substantial foreign contributions. Of course, there is a kind of price. The foreign nations in general want to share in the technology development by contributing interesting components. These will then not be made in the United States.

V. THE IMPACT ON OTHER SCIENCES: BIG VS SMALL

Mr. Chairman, during the years 1984–1989, when I was "on the road" selling SSC to anyone who would listen, I had a disclaimer: "Of course, SSC must be constructed with new appropriations. It would not be acceptable if SSC funds came out of a fixed science budget." This point was accepted by Presidents Reagan and Bush and reiterated by two Secretaries of Energy. Since that time, I have been made keenly aware of the strains in the academic science community, strains which surely exist in spite of very substantial increases in the Federal funding of science.

These strains naturally tend to make the individual investigator sensitive to what he or she would perceive as a diversion of funding to large facilities. This thereby exacerbates the conflict between those scientists that require centrally shared, expensive facilities and the traditional professors who, with a few postdocs and graduate students, do their work on campus.

It seems clear to me that the nation must find a reasonable balance between such shared facilities as telescopes, space observatories, oceanographic vessels, genome biologists, synchrotron light source materials scientists and those individual investigators who are fortunate and clever enough to do their research on a table top in the University. It is also clear to me that in general the nation is, in 1991, underinvesting in science, a statement that echoes such distinguished people as Erich Bloch, Allen Bromley, Frank Press, Congressman George Brown and Senator Al Gore, just to name a few. There are other balances that must be managed here: that between basic research and applied research, that between university research and national laboratory research and it is probably important that the health of industrial research is also of concern to the Congress. In spite of all the stresses on the Federal budget, the long term investments in research and in education are crucial to the well-being of the nation. And in any rational program which permits science a reasonable growth, the SSC should be an important factor.

Senator FORD. Thank you very much, Doctor.

Dr. Fleury, you stated that—and I quote, I think from your statement—"The National priorities have become seriously out of balance and promise to become more so."

What should we do to change our priorities, and specifically, what do we need to start doing differently?

Dr. FLEURY. Well, I think what we need to do is to look with more detail at what is behind the rather impressive overall number in increasing R&D. If you look at the total amount of R&D expenditure at the Federal level in this country, civilian, and defense, the bulk of it is in defense-related. And the bulk of the non-defense-related, or civilian, is in "D," not "R."

Even if you look within "R," people have quoted the increase in the NSF budget, for example, as something to be proud of. It is something to be proud of. But it does not take into account the fact that programs have been mandated to the NSF—and these appropriations, deliberations—which have increased the number of things they are being asked to do, and not provided sufficient funds for them to do these things. And I refer specifically to pre-college education.

For example, something we must do, but it should not be considered as part of our scientific funding budget, particularly when it results in a sub-inflationary increase in the support of the kinds of science—what I call, that lead to what I call "productive research."

So I think looking into those numbers, and finding out for sure what is really happening in terms of what I referred to earlier as a dichotomy between the perception of the Congress and the administration that science is being treated very well, and the perception of the worker at the bench, and the graduate student who is not getting his research supported. That is really, that needs to be looked at more fully.

It is, I think, for all of the problems that this budget cap agreement—I guess the Budget Enforcement Act of 1990—has brought, it has brought home to us the reality that you cannot, as scientists were often fond of saying, well, this is only the cost of one battleship or one bomb, or something like that. It is recognized now that science research is part of the discretionary domestic funding, and that we must—in providing money for something within that pot—take something away from another thing that is in the same pot.

And I think that what we have said here is that the imbalance between the large projects, where a few-percent reduction, let us say, in the cost of the space station or the Supercollider, would fund large amounts of individual investigators. That is the kind of trade-off that has to be made. It does involve cross-field prioritization, something which scientists have been notoriously reluctant to do.

But I think if we do not face up to it, it is going to be faced up to for us. And we may not like the way it comes out.

Senator FORD. What do you mean by that?

Dr. FLEURY. Well, I think as you said, you are going to have to make the decisions. If we cannot give you any help in making those decisions, you will make them with less information and with less certainty as to correctness, as you would if we were willing to give you that information.

I have tried to indicate what I think the priorities are from my perspective. I agree that I am a bench scientist. I have not been involved in large projects. But I have served as the chairman of the Division of Condensed Matter in the American Physical Society. And I believe I am speaking for the vast majority of small scientists. They believe what they do—and I believe they are correct—is intellectually every bit as challenging and productive of intellectual advance as the large project-type research. And yet it has much more direct impact in an economic and technological sense for the country.

And as Professor Bloembergen mentioned, two-thirds of the students educated in these fields—within physics—two-thirds of the students educated in physics do their work in what we call small science.

Senator FORD. Thank you.

Dr. Bloembergen, the APS has taken the position that the SSC should be built in a "timely fashion" but not at the expense of broadly based scientific research. That is a quote from your statement.

Can we afford the SSC without impacting other science programs? And perhaps you might expand on what you meant by "timely fashion."

Dr. BLOEMBERGEN. By "timely fashion" I meant that it should not be stretched out by a factor of two over what is currently envi-

sioned. I think currently the target date for having the machine in operation is about the year 2000. And if it stretches out to 2010 or beyond, then it—you lose it in two ways: in the first place it is likely that it will be overtaken by a new machine at CERN; and secondly, it will be very difficult to keep the morale of the people who are building something, you know, and the participation of foreign nations if this date is moved another scientific generation ahead. Then you might as well wait until the budget situation is better and we can afford to spend it and review the whole thing at a much later date.

But it is very dangerous to go ahead at half-speed. That is one thing.

The other question, I should say, that as president of the Physical Society, I speak for both high-energy physicists and the small-scale, solid-state material science and so on.

Senator FORD. Now, do not tell me you are on both sides. That is the same kind of answer I have been getting all day, too.

Dr. BLOEMBERGEN. And I want to emphasize that the council represents all categories of physicists. And the high-energy physicists agreed with the resolutions, of which you had the text.

Senator FORD. Now, Doctor, we have a funding cap.

Dr. BLOEMBERGEN. Yes.

Senator FORD. And Dr. Lederman said he went out into the highways and bi-ways preaching the gospel of SSC. But he also said it should be "new money" according to his statement a few moments ago.

But the path we are on, as this Senator sees it, that if we completely fund SSC as proposed by the administration and the Department of Energy, we will not have new money, because that means new taxes, and, you know, even Newt Gingrich wanted the President's political head last year, and Pat Buchanan was going to run for President over some new taxes and new money.

So my judgment is that the funding cap out there will be the same for the next 5 years. And so we will impact other scientific programs. And I do not know how we are going to get out of that, unless you have a suggestion for me.

Dr. BLOEMBERGEN. Well, I tried to make the suggestion that the money be found by going very slow, or even abandoning the manned space station. I do not know under which category that falls in your budget. But if you vote for the manned space station, you do not do a favor to science.

Senator FORD. How much money are we talking about, do we know? $2 billion?

Dr. BLOEMBERGEN. $2 billion for the——

Senator FORD. $2 billion this year?

Dr. BLOEMBERGEN. I think you could do more, better space science with unmanned crafts. And if you scrap that very ambitious program, that will require much more than $2 billion in the years following—it is a gigantic project.

Senator FORD. $37 billion, includes R&D, operation through 1999 in real dollars. Does not include any kind of foreign contribution. And fiscal year 1992 is $2 billion, which is an increase of 5 percent.

Dr. BLOEMBERGEN. Yes, so it is an enormous—it is even very large compared to the SSC. And from the point of view of science, I

would say it has very little value, the manned space station. In fact, it is almost detrimental.

Senator FORD. Let me reminisce just a little bit. When I was just a kid, I would get 15 cents on Saturday. Now that does not sound like much. But it got me into the picture show to see the show and the serial that Buck Rogers was—that Buck was jumping off the cliffs. And he would go out and you would have to go back next Saturday to see it. I got my bag of popcorn and my funny book. And it was Buck Rogers. And my grandfather told me I was throwing my money away. And then his grandson came to Washington and was assigned to the Space Committee. And so we are already doing all these things.

So I think that you are absolutely right. And if I have to choose, I am going to be with you on this. Because that way, we have the science that you have on your right, and you have the SSC on your left. And the other can float around in our minds for a while, rather than begin to float around in space.

Dr. BLOEMBERGEN. Put it on the back burner, where there is no competition there. And by the year 2000, we may decide that we have the money to go forward with the manned space station.

Senator FORD. Dr. Lederman, let me—I know you support the SSC, and you have said that publicly. And you have been a promoter of it. And you also support small science getting more money.

Let us just say that once SSC is in operation, should we close down any of the existing accelerators? And if so, which ones?

Dr. LEDERMAN. Wow.

Senator FORD. I thought I would have a good time today.

Dr. LEDERMAN. Yes, I know you are having a good time.

I think we ought to—yes, I think we ought to look closely at the existing accelerators. Probably, we will not have to do anything for some time. At the moment, there are four places in the United States where you can do high energy physics. Fermilab is the major place today. Stanford is operating a different kind of machine. Brookhaven is changing over to a different kind of physics, but they are still doing significant particle physics, and there is a small accelerator at Cornell.

I support the National Science Foundation. I think when the SSC comes on my guess is we will be down to two laboratories. But that is a guess. Everything depends on scientific possibilities. It is they projecting 10 years ahead, or 8 years ahead, when we begin to see these things.

And we are also projecting sort of the general attitude—today's attitude on 10-year-from-now science budgets, which we also do not know. But we can be optimistic, which I am, of course.

Senator FORD. Most scientists are.

Dr. LEDERMAN. Yes, I know. You know, it was pointed out, high-energy physics is a planning sort of an organization that sort of pioneered within that community planning its futures. And those 20 accelerators were closed deliberately by a committee. It was called HEPAP. It was an advisory committee to the Atomic Energy Commission, and then ERDA, and now DOE. And little by little we started—we said, we have to close laboratories in order to gain enough funds to build the new facilities which will address the issues that we have to address.

And that has been something that is well known. We have planned this. And so there is an outline, a plan, and an organization that looks 10-years ahead. And that is why we are on this SSC kick. We would all love to be able to build the SSC or do that physics with a hairpin and tweezers and a test tube. We do not know how to do that. That is the problem with all of this.

Senator FORD. Let me ask the panel this question.

Would it make senses to develop the magnets and other key components of the SSC first. And then if these developments are successful, then commit to the full-scale funding of SSC?

Dr. LEDERMAN. Well, let me say a bit about the magnets. Because all the laboratories have capability. Fermilab has been very active in building prototype magnets for the SSC. And so has Brookhaven, and so has the laboratory in Berkeley.

I think we have a good understanding of the magnets. I think the magnet problem—and the plan, the plan for DOE is that industry will come to Fermilab and Brookhaven, and LDL, and begin to learn how to do this prototyping. And then eventually turning prototypes over the industry—it is a very well-thought-out plan which gives industry incentives and makes them compete with one another in order to make sure that we have a good product.

The biggest problem, my biggest concern, is we could build these magnets. When Fermilab built its accelerator, the magnets were built in the laboratory by laboratory personnel using vendors to supply all the parts. You cannot do that with this big a project.

But we do not see any difficulties except the industrialization. That is the big problem. Can industry really handle—can American industry really handle a technological challenge of this magnitude to produce these magnets, which are very intricate, very complicated.

And, you know, our record has not been all that great in industrialization of large, very high technology production of this kind. And so that is a concern. But it seems to be very well thought out. I do not see a magnet problem. And certainly there will be a string of—several strings of magnets running day and night. There is already a string of magnets with prototypes, just pulsing every day, day after day.

As we develop more prototypes, they will enter the stream of testing. And by the time there is any serious tunnel digging, there ought to be 100 magnets on line, if I remember the schedules roughly, being pulsed, being tested, being measured.

Senator FORD. You mean under the present schedule as DOE has outlined?

Dr. LEDERMAN. As I understand them, that is right. Some large number.

Senator FORD. So we do not have to worry about having magnets in place under that schedule, with the tunnel and so forth?

Dr. LEDERMAN. I think that the empty tunnel syndrome or lesson has been very well learned by the Department of Energy and everybody else.

Senator FORD. If we wind up with some funding restraints, or constraints, that must be imposed on SSC, how could we modify it so we would not lose the challenge and be able to accommodate some constraint in funding?

Dr. LEDERMAN. Well, the $8-something billion has a very large contingency. I mean, I feel pretty comfortable with that number, although I have not examined it. It is an intuitive feeling that comes from the fact that we built an accelerator which in 1990 dollars cost $1 billion or so. So it was not all that small. I think that there is almost a billion of contingency in that I think that is enough to cover lots of possibilities that we have not thought of, or funding profile problems that may come about. There may be even more contingency in their hidden contingencies, and the conservatism with which various components have been cost-estimated. And so to some extent, you can accommodate the problems you have mentioned.

Senator FORD. Well, what about the $1.7 billion in foreign contributions, and a billion that they look at Texas for—and Texas is on schedule with their payments. We have not been able to secure the foreign input. And as I asked Secretary Moore, and he shows us the years that they would need the money, $140 million, $150 million, and so forth. And as time slips on that, Doctor, that amount of money would have to come from here if we don't get it from over there.

Dr. LEDERMAN. I share your concerns.

Senator FORD. They do have $1 billion and they are still $1 billion short, if the foreign investments are not available. Maybe I am too conservative. Maybe I ought to be like others and say everything is going to be all right. Just have faith.

But my bible says faith without works is dead. And so I have a lot of faith. But I want to work at it and be sure that when I look back over my shoulder we have not created another fiscal fiasco.

Does anybody have any statements you would like to make? We are going to close down here. I have been tickled to death to have all of you here. And I am sorry I get so excited and ask so many questions.

Dr. LEDERMAN. I think if the DOE does not come up with hard agreements by next year, you ought to really get tough, sir.

Senator FORD. Thank you. I am. You just—you gave me a decision. And you do not have to be placed in the same position as Dr. Bromley. I understand that. He is a good soldier and he is going to march to the tune. And Senator Craig says I will never get an answer. But I just got an answer.

Well, we will see about that.

If there are no further statements by you gentlemen, this hearing is adjourned.

[Whereupon, at 4:15 p.m. the hearing was adjourned.]

[The subcommittee received the following for the record:]

Ocala, FL, April 7, 1991.

Hon. J. BENNETT JOHNSTON,
Chairman, Committee on Energy and Natural Resources, U.S. Senate, Washington, DC.

Reference my letters dated 28 February and 4 March 91 in which I gave you irrefutable proof that Einstein's Special Theory of Relativity is false and that, as a result, the Superconducting Super Collider (SSC) would be a worthless scientific instrument.

Inclosed is my written testimony on the FY 92 SSC budget proposed by DOE. It is for consideration at the SSC hearing to be held on 16 April by your subcommittee on Energy R&D and for inclusion in the official records of the hearing.

Please reply to my letters.

Steve Stoll.

[Enclosure.]

THE SSC—A WORTHLESS SCIENTIFIC INSTRUMENT

I hereby give written testimony regarding the Superconducting Super Collider (SSC) to the U.S. House of Representatives Committee on Science, Space and Technology and the U.S. Senate Committee on Energy and Natural Resources. This testimony is offered for consideration at the forthcoming hearings to be held by the House and Senate Subcommittees on Energy R&D on the FY 92 SSC budget proposed by the Department of Energy, and is intended for inclusion in the official record of the hearings.

This testimony proves that the SSC would be worthless as a scientific instrument because Albert Einstein's Special Theory of Relativity has serious flaws which make the theory untenable.

In part 1 of this testimony, I will address Appendix 1 and you will see the flaws in Einstein's theory. In part 2, I will address Appendix 2 and you will see why the maximum SSC proton kinetic energy will be less than one percent of the minimum required.

PART 1

Let's start at the top of Appendix 1. According to Isaac Newton, the velocity of any object could, theoretically, be made to increase without an upper limit—no upper bound—and the mass of an object always had a constant value. Equation 1 is Newton's formula for momentum. It is mass (designated as m) multiplied by velocity (designated as v). Equation 2 is Newton's expression for centrifugal force. That's the way it was until early in the 20th century when the concepts of velocity and mass changed radically. In his Special Relativity, published in 1905, Einstein gave velocity an upper limit, which is the speed of light, and he allowed mass to increase with velocity.

Equations 3 and 4 are Einstein's formulas for momentum and centrifugal force, where m/Y is the velocity dependent mass and s is the velocity. The radius of curvature of an object is R. The Y factor, commonly known as the Lorentz transformation factor, transforms Newton's mass into a relativistic mass (note: the c in the Y factor is the speed of light). Since Einstein gave velocity an upper limit, equations 3 and 4 are seriously deficient because they fail to show how the velocity is different from that of Newton.

For any given momentum, equations 1 and 3 may be set equal as shown in equation 5. The m cancels out, yielding equation 6 which shows the relationship between v and s. Einstein made a blunder. The Y factor cannot apply to mass because it obviously applies to velocity. Equation 6 can be transposed to equation 7. Combining equations 6 and 7 yields equation 8.

Column 1 of the table shows selected values of v/c. Column 2 shows corresponding values of s/c. Column 3 shows corresponding values of proton kinetic energies in billions of electron volts.

Imagine a moving electric charge bending in the arc of a circle of radius R due to a magnetic force. For any given centrifugal force, which is equal and opposite to the magnetic force, equations 2 and 4 may be set equal as shown in equation 9. Both m and R cancel out to yield equation 10 which contradicts equation 6. Since equation 6 gives the correct relationship between v and s, equation 10 is false, and it follows that Einstein's formula for centrifugal force is also false.

PART 2

Equations 11, 12 and 13 of Appendix 2 are the same as equations 6, 7 and 8 of Appendix 1. We need to keep them visible. Equation 14 is Einstein's energy equation where K represents kinetic energy. We may substitute Z for 1/Y to get equation 15. Equations 14 and 15 are equivalent. At high energies, the expression (1/Y – 1) reduces to 1/Y and (Z –1) reduces to Z. Further, Z reduces to v/c and equations 14 and 15 reduce to equations 16 and 17.

Consider a magnetic force, designated as Bqs, acting on an electric charge designated as q. The magnetic flux density is B. We may substitute v/Z for s. The magnetic force without Special Relativity is Bqv/Z. The two expressions are equivalent as shown in equation 18.

Equations 19 and 20 show the relationships between magnetic and centrifugal forces, with and without Special Relativity. Equation 19 is false because Einstein's expression for centrifugal force is false.

In a synchrocyclotron, the values of B, q and m are known. Combining equations 19 and 20 yields equation 21 which transposes to equation 22 because $YZ=1$. The radius of curvature associated with s is designated as R′ because it is different from that associated with v. The ratio v/s is equal to the ratio R/R′. The particle revolution times and frequencies are the same. Both v and s synchronize with the decreasing radio frequency accelerating voltage. Equations 19 and 20 both agree with experiment. Synchrocyclotrons work without Special Relativity.

In a synchrotron, the values of B, q, R and m are known. Combining equations 19 and 20 yields equation 23 which contradicts equation 11, so that the transformation factor and velocity in equation 23 are now designated as s′ and Y′. Further, kinetic energy as related to synchrotrons will be designated as K′. Dividing vZ and s′/Y′ by c yields equation 24.

Since equation 19 is false, there can be no doubt that the operation of a synchrotron is in accordance with equation 20. The ratio of the radio frequency (rf) voltage (applied at the accelerator gap), to the particle revolution frequency (prf), decreases as v and B increase, even after the rf reaches a constant value. Computer programs allow the rf to follow and synchronize closely with v and B. Sensing devices detect changes in R and send the information to a computer, which then adjusts the radio frequency and phase to maintain synchronization as the prf increases and rf/prf ratio decreases.

At synchrotron high energies, equation 24 reduces to equation 25 because Z reduces to v/c and s′/c becomes 1. Equation 16 must be modified as shown in equation 26. Combining equations 25 and 17 yields the left side of equation 27, and combining equations 25 and 26 yields the right side. Equation 27 can be transposed to equation 28.

Refer to the table at the bottom of Appendix 2. The maximum energy of the counter-rotating protons in the SSC is expected to be 20000 GeV (collision energy: 40000 GeV) which is the minimum required to test the Grand Unified Theories and the Standard Model of Physics. In equation 28, we may substitute 0.93828 GeV for mc^2 and 20000 GeV for X′. We find that K, the true particle energy, is 137 GeV which is less than one percent of the minimum required. Further, according to Fermilab, the Tevatron has achieved 900 GeV. But the true proton energy is only 29 GeV.

EPILOGUE

In his later years, Einstein had serious doubts about his Special and General Theories of Relativity. In a letter to a friend dated 28 March 1949 he wrote: "You imagine I look back at my life's work with calm satisfaction. But from nearby it looks quite different. There is not a single concept of which I am convinced that it will stand firm, and I feel uncertain whether I am in general on the right track."

I wrote this testimony so that the main points, if studied slowly and carefully, could be followed and understood by reasonably intelligent people, including members of Congress, with a knowledge of elementary algebra. Physicists, including advisors to congressional committees, should have no difficulty whatsoever. They will find that the evidence is irrefutable.

Those of you who understand my testimony are now aware of the flaws in Einstein's theory and the catastrophic impact on the SSC. With this knowledge, can you honestly and ethically continue to support the SSC? The project should be terminated. There is no moral alternative. Any remaining FY 91 funds and any funds appropriated for FY 92 should be limited to phasing out the program.

Isaac Newton:

Velocity: No Upper Bound

Mass: Constant for any given object

Momentum = mv (1)

Centrifugal Force = mv^2/R (2)

Albert Einstein: Special Relativity

Velocity: Upper bound is speed of light

Mass: Velocity dependent: equals m/Y

Momentum = ms/Y $Y = (1 - s^2/c^2)^{1/2}$ (3)

Centrifugal Force = ms^2/RY (4)

Comparison of v and s:

$mv = ms/Y$ (5)

$v = s/Y$ (6)

$s = v/Z$ $Z = (1 + v^2/c^2)^{1/2}$ (7)

$YZ = 1$ (8)

v/c	s/c	K (GeV)
0.1	0.0995	0.005
1.0	0.7071	0.39
10	0.9950	8.49
100	0.9995	92.9

$mv^2/R = ms^2/RY$ (9)

$v = s/Y^{1/2}$ (10)

Appendix 1

42-959 0 - 91 - 3

$v = s/Y \qquad Y = (1 - s^2/c^2)^{1/2}$ (11)

$s = v/Z \qquad Z = (1 + v^2/c^2)^{1/2}$ (12)

$YZ = 1$ (13)

$K = mc^2 (1/Y - 1)$ (Einstein energy equation) (14)

$K = mc^2 (Z - 1)$ (15)

$K/mc^2 = 1/Y$ (high energy) (16)

$K/mc^2 = v/c$ (high energy) (17)

$Bqs = Bqv/Z$ (18)

$Bqs = ms^2/RY$ (19)

$Bqv/Z = mv^2/R$ (20)

$Bq/m = vZ/R = s/YR'$ (synchrocyclotron) (21)

$v/s = R/R'$ (22)

$BqR/m = vZ = s'/Y'$ (synchrotron) (23)

$(v/c)Z = (s'/c)/Y'$ (24)

$(v/c)^2 = 1/Y'$ (high energy) (25)

$K'/mc^2 = 1/Y'$ (26)

$(K/mc^2)^2 = K'/mc^2$ (27)

$K = (K'mc^2)^{1/2}$ (28)

	K' (GeV)	K	v/c
Tevatron	900	29	32
SSC	20000	137	147

Appendix 2

APPENDIX

RESPONSES TO ADDITIONAL QUESTIONS

Department of Energy
Washington, DC 20585
May 22, 1991

The Honorable Wendell H. Ford
Chairman
Subcommittee on Energy Research and Development
Committee on Energy and Natural Resources
United States Senate
Washington, DC 20510

Dear Mr. Chairman:

On April 16, 1991, W. Henson Moore, Deputy Secretary, testified before your subcommittee on the Department of Energy's Superconducting Super Collider program.

Following the hearing, you submitted written questions to supplement the record. Enclosed are the answers. The remaining answers to questions 3 and 10 are still in the clearing process and will be forwarded to you as expeditiously as possible.

If we can be of further assistance to you or your staff, please contact our Congressional Hearing Coordinator, Barbara Campbell, on (202) 586-8238.

Sincerely,

Jacqueline Knox Brown
Assistant Secretary
Congressional and Intergovernmental Affairs

Enclosures

Department of Energy
Washington, DC 20585
May 24, 1991

The Honorable Wendell H. Ford
Chairman
Subcommittee on Energy Research and Development
Committee on Energy and Natural Resources
United States Senate
Washington, DC 20510

Dear Mr. Chairman:

On April 16, 1991, W. Henson Moore, Deputy Secretary, testified before your subcommittee on the Department of Energy's Superconducting Super Collider program.

At the time of my last letter to you dated May 22, 1991, responses to questions 3 and 10 were still outstanding. Enclosed are the responses to those questions.

If we can be of further assistance to you or your staff, please contact our Congressional Hearing Coordinator, Barbara Campbell, on (202) 586-8238.

Sincerely,

Joseph C. Kaspinski for

Jacqueline Knox Brown
Assistant Secretary
Congressional and Intergovernmental
Affairs

Enclosures

Question #1: Provide a magnet development schedule which shows all of the testing, development, and industrial production stages for each type of magnet expected to be produced.

Answer: Attached are the following exhibits which provide information on the magnet development schedules.

Exhibit 1. A magnet table of every required magnet

Exhibit 2. Master schedule for collider dipoles

Exhibit 3. Master schedule for collider quadrupoles

Exhibit 4. Schedule of magnet monthly deliveries

Exhibit 5. Generic superconducting magnet development schedule

Each type of magnet is developed to the same basic schedule with small variations due to the different numbers of prototype or preproduction magnets. Times are based upon the collider dipole magnet schedule. Other magnets will vary depending on individual contractor capabilities.

Magnet contractor development efforts focus on the design and testing of likely production design candidates which would satisfy the performance requirements at the highest reliability and lowest overall program cost.

The performance requirements are finalized with results from the laboratory magnet tests and the string tests. The cost and schedule objectives were established in the baseline cost estimate, based upon top-level performance objectives. A baseline design, satisfying all program requirements, is established with the magnet contractor using all available data from technology transfer out of the labs and SSC specifications. Prototype testing provides the opportunity to evaluate variants of the baseline design which could improve the production magnet. Preproduction testing is the final step in the development process that will result in a fully-evaluated design and production process prior to beginning production.

Magnet Table Buy Options[1]

Superconducting Magnet		Parameters			Quantities (Cold Masses)							First Production Unit Availability (On Dock at SC or MDL) from MSD	First Production Unit Required (On Dock at SC or MDL) by ASD	Notes
	MMS				SSC Models(1)	Non-SSC Models	Prototype		Pre-Production	Production	Delta to SCE Quantities			
		Peak Operating Field	Magnetic Length (m)	Aperture (mm)			SSC	Industry						
CDM 15m	1.2.3.1	6.6 T	15.17	50	4X3	4*+3#	13P+1L	10	65	7950	- 8		7/94	
CDM 13m	1.2.3.2	6.6 T	12.84	50				3	3	504	+ 8		8/94	
BV2-	1.2.3.10	6.6 T	12.84	50						48	0		3/96	Std. 13m CDM - 80° Cryo
BV1+	1.2.3.4	4.4079 T	5.00	50				2	2	48	0		3/96	Std. 13m CDM - 2 in 1 Cryo
M-1	1.2.3.0	180 T/m	7.125	50				4	4	64	0		10/95	2 in 1 Cryo Std. CDM Cold Mass
QLR	1.2.3.5	180 T/m	6.79	50	2X3			8	10	256 (3 L)	128		5/97	Shorter Quads (SSCL Quad)
QL8	1.2.3.6	180 T/m	6.79	50						8	0		6/97	
QSD8/QSF2	1.2.3.7	211 T/m	6.67	40						8	0		6/97	
QL8	1.2.3.6	211 T/m	6.67	40						72	0		6/97	
QLN	1.2.3.9	211 T/m	6.67	40						8	0		6/97	
QSD1	1.2.3.7	211 T/m	6.67	40						8	0		6/97	
QSF1	1.2.3.7	211 T/m	6.67	40				2		48	0		6/97	
HEBDM	1.2.2.1	6.39 T	15.17	50						48	0		6/97	
HEBDM(short)	1.2.2.2	200 T/m	1.23	50	2	4(@)+8(#)	2	6	20	432	0		5/98	(@) = KEK, (#) = Industry
HEBDM(long)	1.2.2.3	200 T/m	3.84	50		3(@)		3	9	234	0		5/98	(@) = Saclay Models
CDM	1.2.3.3	211 T/m	6.67	40				3	6	44	0		5/98	
SUBTOTAL					20	23(@)	28	39	131	11366			7/94	(3) Cryostated at SSCL
														(@) KEK Units at No Cost to SSCL

SPECIAL CASE - BUY OPTION UNDETERMINED/OPEN

QL6	1.2.3.6	211 T/m	4.78	40	3X3(#)				1	8	0		5/97	"Soft Design" Possible LBL Build
QM6	1.2.3.6	211 T/m	4.78	40						8	0		3/98	"Soft Design" Possible LBL Build
SUBTOTAL					9				1	16	0			

Magnet Table SSCL MOL Make

Superconducting Magnet		Parameters			Quantities (Cold Masses)							First Production Unit Availability (On Dock @ MDL)	First Production Unit Required (On Dock @ MDL)	Notes/Rationale
	MMS				SSC Models(1)	Non-SSC Models	Prototype		Pre-Production	Production	Delta to SCE Quantities			
		Peak Operating Field	Magnetic Length (m)	Aperture (mm)			SSC	Industry						
QL5	1.2.3.6	180 T/m	14.26	50			2		3	8	0	6/94	5/97	"Soft Design" Host Load/I-Feed
QM5	1.2.3.6	180 T/m	14.26	50						8	0	9/94	3/98	
QL1	1.2.3.6	230 T/m	15.14	40	3		1		1	4	0	1/95	5/97	
QL3	1.2.3.6	230 T/m	12.86	40					1	4	0	1/96	6/97	
QL2	1.2.3.6	230 T/m	11.22	40					1	8	0	7/96	6/97	Dipoles Made-333 Tm
QL4	1.2.3.6	230 T/m	11.22	40						8	0	10/96	6/97	" " " "
QM3	1.2.3.6	230 T/m	11.22	40						4	0	12/96	9/98	" " " "
QM4	1.2.3.6	230 T/m	11.22	40						8	0	1/97	3/98	
QM1	1.2.3.6	230 T/m	8.5	40					1	4	0	6/97	3/98	
QM2	1.2.3.6	230 T/m	8.5	40						8	0	8/97	3/98	
BV1-	1.2.3.4	4.4 T	5.0	75-100	525		3			32	0	10/97	10/95	Very High Field Quality
SUBTOTAL					21		6		6	96	0			
TOTAL					41	23(@)	34	39	139	11474	+88*			
DELTA TO SCE					-4	+23	+5	-34	+14					(@) KEK Units at No Cost to SSCL
														All numbers are cold mass qty.

Rationale:

- Length Commonality
- High Field Design @ SSCL
- Interaction Region @ SSCL, Dictated By Need Date
- "Soft Design" @ SSCL (Later Option for Change)
- Familiar Design @ SSCL

* Increase -40 of M-1 assumed @ 7.125m in original SCE

Note:

- First production unit availability is based on make schedule dated 4/9/91

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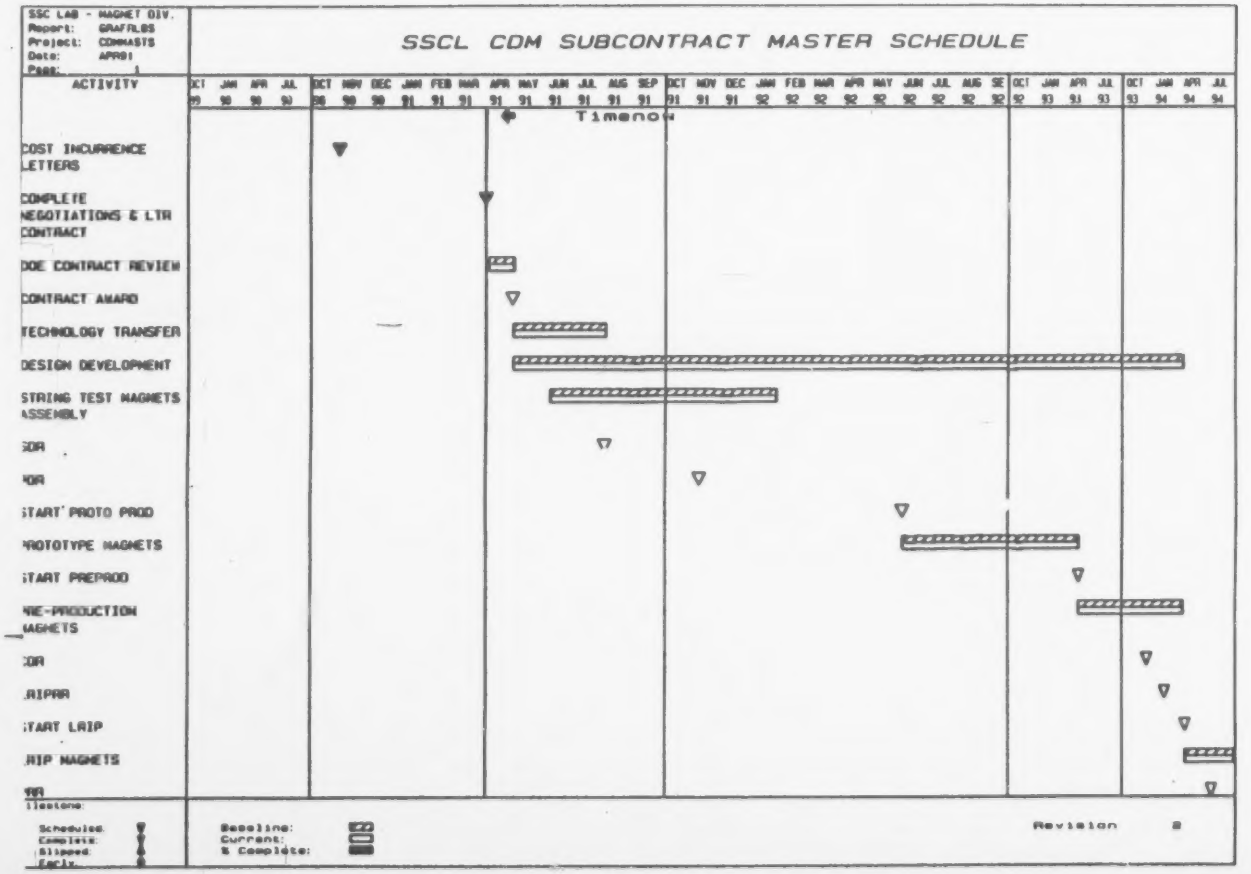
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Report: GRAFBL8S
Project: COMMASTS
Date: APR91
Page: 1
SSCL COM SUBCONTRACT MASTER SCHEDULE
ACTIVITY
Timenow
COST INCURRENCE LETTERS
COMPLETE NEGOTIATIONS & LTR CONTRACT
DOE CONTRACT REVIEW
CONTRACT AWARD
TECHNOLOGY TRANSFER
DESIGN DEVELOPMENT
STRING TEST MAGNETS ASSEMBLY
SDR
PDR
START PROTO PROD
PROTOTYPE MAGNETS
START PREPROD
PRE-PRODUCTION MAGNETS
CDR
ARIPRR
START LRIP
LRIP MAGNETS
ORR
Milestone:
Scheduled:
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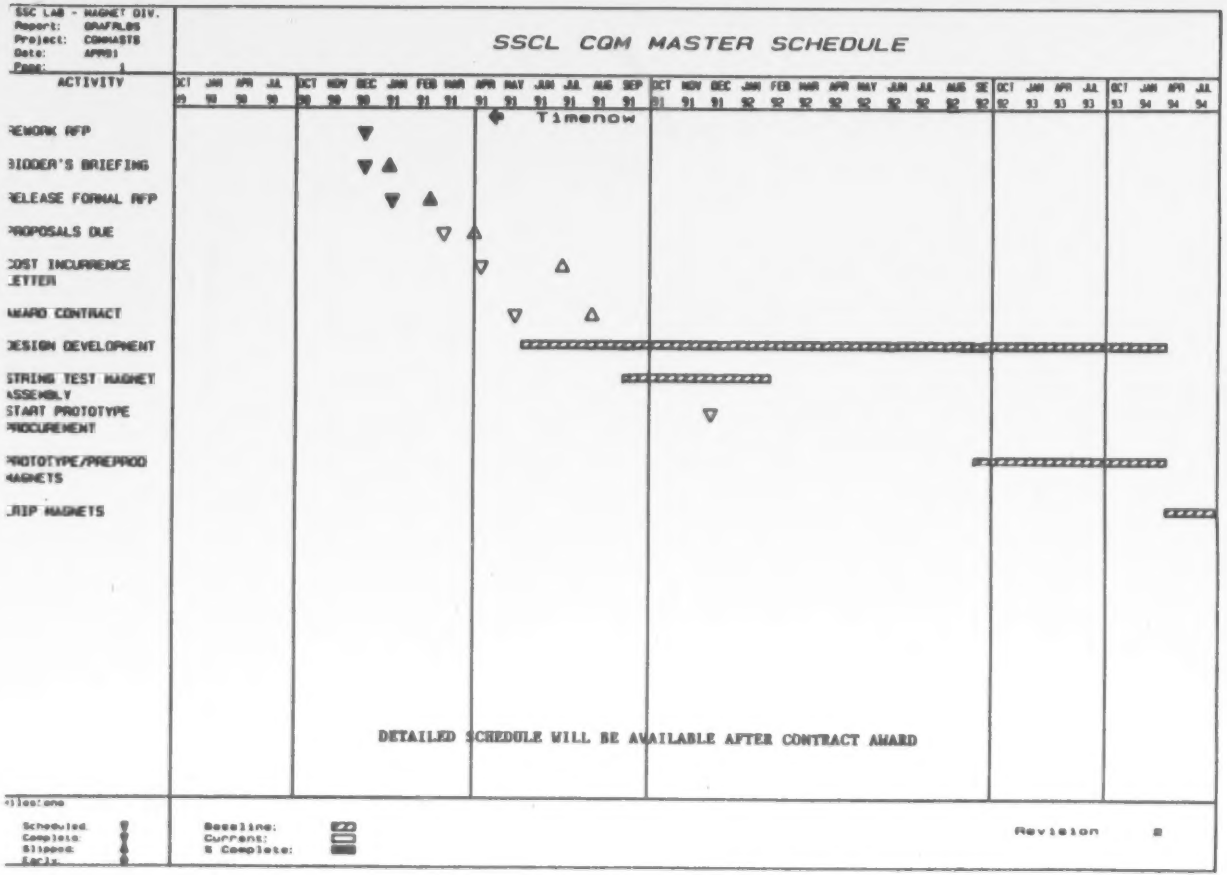
Early:
Baseline:
Current:
% Complete:
Revision 8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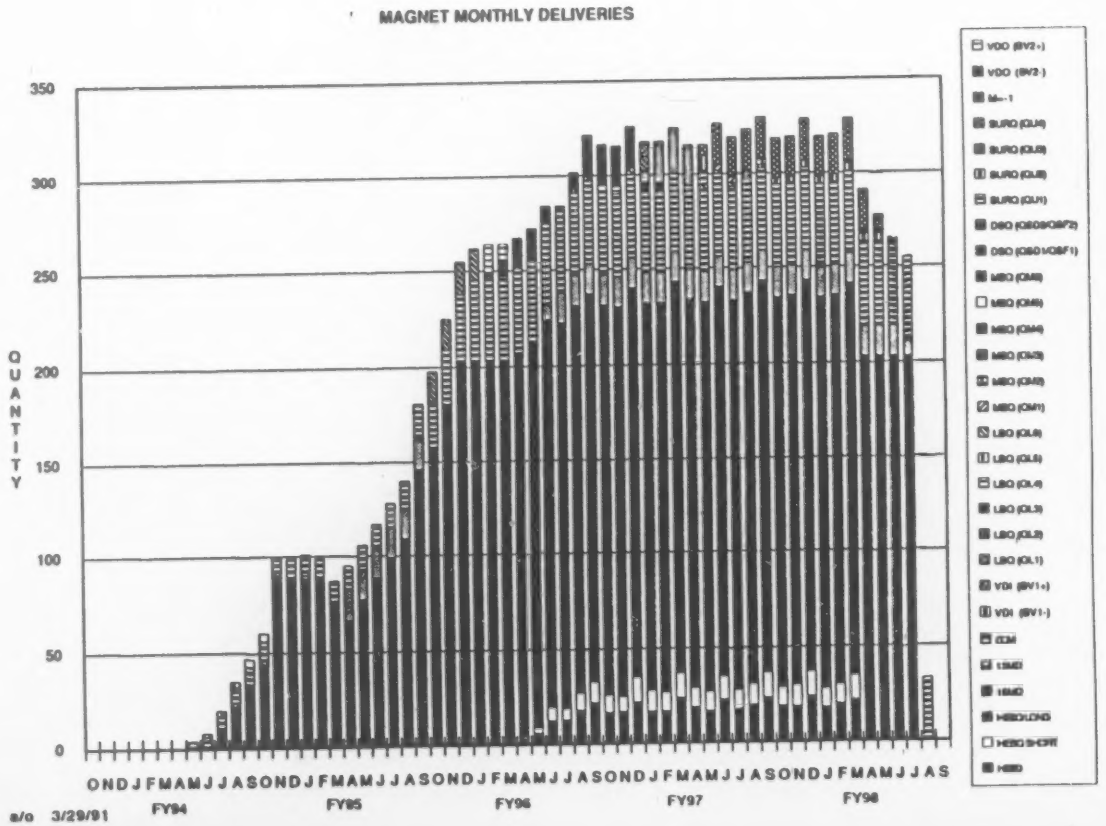
Report: GRAFRLBS
Project: CONMASTB
Date: APR91
Page: 1
SSCL CDM MASTER SCHEDULE
ACTIVITY
Timenow
REWORK RFP
BIDDER'S BRIEFING
RELEASE FORMAL RFP
PROPOSALS DUE
COST INCURRENCE LETTER
AWARD CONTRACT
DESIGN DEVELOPMENT
STRING TEST MAGNET ASSEMBLY
START PROTOTYPE PROCUREMENT
PROTOTYPE/PREPROD MAGNETS
TRIP MAGNETS
DETAILED SCHEDULE WILL BE AVAILABLE AFTER CONTRACT AWARD
Milestone
Scheduled
Complete
Slipped
Early
Baseline:
Current:
% Complete:
Revision


MAGNET MONTHLY DELIVERIES
QUANTITY
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300
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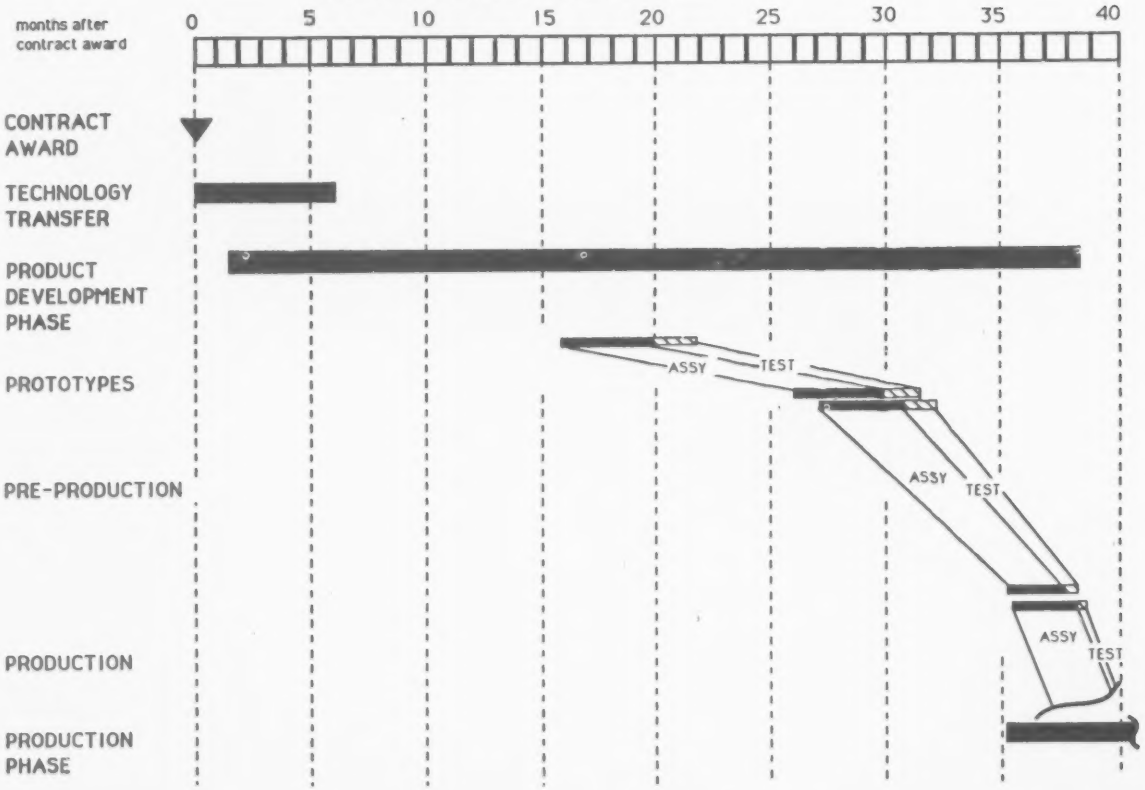
FY98
a/o 3/29/91

SUPERCONDUCTING MAGNET DEVELOPMENT SCHEDULE



Question #2: In the Department's answers to the 1990 Superconducting Super Collider prehearing questions, the Department projected the high energy physics budget, not including the SSC, for 1992 to 1995 to be a total of $2.767 billion. The Department now projects a total budget of $2.664 billion for the same period.

These figures indicate that the Department now expects to request $103 million less for the next four years than last year for high energy physics. Similarly, the Department expects to request $47.5 million less for nuclear physics. Why does the Department expect to request less money in these two budget categories this year than it did last year? What has changed since last year?

Answer: The President's FY 1992 budget request reflects decisions mutually arrived at during last year's budget summit negotiations. As a result of the budget summit agreement, caps were placed on the categories of defense, domestic discretionary and international spending to produce significant deficit reduction over the FY 1991-FY 1995 time period. These caps dictate lower outyear funding profiles compared to previous outyear profiles.

Question #3: The Department expects to hold funding levels for most basic science programs at FY 1992 levels. What impact will holding funding levels at 1992 levels have on basic science programs? Will this cause any of the Department's facilities or programs to be reduced below current levels? Will staff levels need to be reduced? Will staff salaries be kept in line with inflation?

Answer: With the exception of the SSC, the Human Genome, High Performance Computing and Communications, Global Climate Change and Education initiatives the Department's outyear projections for FY 1993 - FY 1996 associated with the President's FY 1992 budget request hold funding at FY 1992 levels. At this level, staff salaries will not be kept in line with inflation, and programs will decrease by the amount of inflation each year.

Question #4: I am concerned that, in order to reduce expenditures for other basic science facilities the Department will or has already reduced the operation of some of these facilities. Has the Department taken, or does it plan to take, such action? For the record, please provide the following:

For each of DOE's major facilities provide the total number of days of operation for 1990, the total number planned for 1991 and the total number proposed for 1992;

For each facility, please explain any increases or decreases in the number of days of operation from 1990 to 1991 and from 1991 to 1992;

For each facility, please explain if it is operating at full capacity and if funding constraints have in any way limited the facility's operation or is expected to do so.

Answer:

Basic Energy Sciences

	Days of Operation		
	FY 1990	FY 1991	FY 1992
National Synchrotron Light Source			
VUV	210	308	308
X-Ray	210	280	280
High Flux Beam Reactor	0	140	335
Intense Pulsed Neutron Source	161	182	182
High Flux Isotope Reactor	182	336	336
Radiochemical Engineering Development Center	182	336	336
Stanford Synchrotron Radiation Lab	63	210	210
Manuel Lujan, Jr. Neutron Scattering Center	126	182	182
Combustion Research Facility	365	365	365

The overall Basic Energy Sciences Congressional Budget Request and Congressional Appropriation for FY 1991 included a budget increase specifically to allow for higher levels of facility operations. The Department proposed and the Congress agreed that higher utilization of the facilities was necessary to meet user needs and the FY 1991 and FY 1992 budgets recognized the important role these facilities play in advancing science and technology.

Four of the Basic Energy Sciences facilities are proposed to operate at full capacity in FY 1992 -- the two research reactors, the High Flux Isotope Reactor and the High Flux Beam Reactor; and the National Synchrotron Light Source and the Combustion Research Facility. The other BES user facilities, are operating at levels which are consistent with the research needs at these facilities.

High Energy Physics -

	Days of Operation		
	FY 1990	FY 1991	FY 1992
Fermilab Tevatron.....	196	140	266
Stanford Linear Collider.....	112	140	154
Alternating Gradient Synchrotron..	105	84	112

Overall operating hours in FY 1991 were reduced due to a Congressionally mandated general reduction to the General Science appropriation. The reduction in High Energy Physics was $32.6 million.

The running time at Fermilab in FY 1991 has been reduced to allow access for improvements to the accelerator and beam line shielding. In FY 1992, Fermilab will be operated at full capacity.

The Stanford Linear Collider (SLC) running time in FY 1990 was substantially below full capacity due in part to the machine studies and corrective work needed to improve the SLC luminosity, and in part due to the effects of the San Francisco earthquake in October 1989. In FY 1991, there

continued to be substantial work aimed at improving the SLC luminosity. The FY 1992 running time is further increased but is short of full operation due, in part, to continuing work on the SLC luminosity.

The changes from year-to-year for the Alternating Gradient Synchrotron (AGS) reflect variations in the details of the planned experimental program. In all three years, the AGS is being operated at less than full capacity in line with the overall priorities of the HEP program.

Nuclear Physics	Days of Operation		
	FY 1990	FY 1991	FY 1992
ANL Tandem/Linac Accelerator System.....	221	136	a/
BNL Tandem/AGS Heavy Ion Facility.....	40	50	70
Bevalac.....	264	229	224
88-inch Cyclotron.....	354	261	a/
Los Alamos Meson Physics Facility.....	177	136	133
Bates Linear Accelerator Center.....	132	86	35
Holifield Heavy Ion Facility.....	293	250	a/

a/ To be determined in response to NSAC recommendations.

Operating hours in FY 1991 were reduced due to a Congressionally mandated general reduction to the General Science appropriation. The reduction in Nuclear Physics was $17.4 million.

Operating hours were curtailed in FY 1991 at The Argonne Tandem/Linac accelerator in order to install improved safety equipment.

Operating hours were curtailed at the Bates accelerator to install South Hall Ring Experiment.

Question #5: Some scientists are pushing to widen the aperture of the quadrupole magnets from 40 to 50 millimeters. Could you explain why these scientists want the aperture to be increased?

Regardless if it is necessary or desirable to make the increase, how much would it cost if the size was increased? What is the likelihood of making the increase in size? When will we have the definitive answer as to whether there is a need for the increase?

Answer: Individual scientists at the SSC Laboratory have suggested that the aperture of the collider quadrupole magnets be widened, primarily to increase the flexibility in design approaches for dealing with machine vacuum degradation over time and possible future luminosity upgrades. However, in careful analysis by the SSC Laboratory, it has not been demonstrated that this change is necessary to meet the performance objectives of the SSC, and the SSC Laboratory Project Manager has informed the Department that he does not intend to submit it as a design change to the Change Control Board.

An increase in quadrupole aperture is not essential to achieve machine performance; in fact, machine design margin might actually decrease in some areas. However, an increased aperture, in conjunction with the use of a beam tube liner, would present greater opportunities for machine upgrade than the present design. The cost of such a change, if it were to be considered as a scope increase, is not known at this time.

In summary, the SSC Laboratory has not proposed such a

change and the Department does not plan to consider a change in scope beyond that of the baseline.

Question #6: Since most of the contributions from foreign sources will be in-kind, at some point it becomes too late to accept foreign contributions. For each major SSC component or system, indicate when it is too late to accept foreign contributions.

Answer: Based upon the milestone schedules developed for the collider and the scheduled commissioning dates for the Low Energy Booster (LEB), Medium Energy Booster (MEB), and High Energy Booster (HEB), the Department has examined the schedules needed for the various components to support each facility. This has led to a time period by which we must have formal agreements and commitments to deliver components or systems. These dates for the major systems and components are shown below:

Linac	Design already underway
MEB & LEB Accelerator	Late 1992
HEB Accelerator	Early 1993
Collider Dipole & Quadrupole Magnets	Mid 1993
Superconducting Cable for Collider Magnets	Mid 1993
RF Systems	Early 1993 to Late 1994 (depending on system)
Bulk Power Supplies	Early 1994
Cryogenic Systems	Mid 1994

These time periods represent the latest reasonable time for an agreement to be in place to produce the major component or system shown. In the case of

complete systems, the foreign participant would be required to have physicists and engineering expertise, as well as production capability, available on or soon after this date in order not to impact the program schedule.

Question #7: If the Department receives the full amount of its funding request for each year of the duration of the project, will:

the SSC be completed before its currently scheduled completion date?

will the SSC be built at a cost less than the Department's current estimate? If so, by how much less?

will the need for foreign contributions be reduced? If so, by how much?

Answer: The baseline report presents a schedule and Total Project Cost that, coupled with the funding profile, will result in the completion of a successful project on schedule and within budget. With full funding in FY 1992, we will be able to maintain the momentum and pace of activities we now have in accordance with the baseline. Although we have achieved some savings in FY 1990 and to date in FY 1991, it is premature at this early stage of project execution to speculate on the total magnitude of possible savings. The Department's goal remains to obtain one-third of the Total Project Cost through non-Federal contributions.

Question #8: The Department has selected General Dynamics and Westinghouse to build the dipole magnets. Will one of these companies end up building all of the magnets?

Answer: General Dynamics and Westinghouse will build enough dipole magnets for the collider to allow both to provide highly competitive fixed-price bids for the bulk of the production. The development contracts with these two companies will provide for the transfer of superconducting magnet technology from the laboratories to industry, followed by a period of producing prototypes and preproduction magnets, culminating in the low-rate production of 250 magnets by each company in FY 1994 and early FY 1995. At that time, based on the price variance with quantity and consideration of various risk factors, a decision will be made on whether to retain both or only one vendor.

Question #9: If foreign countries do end up building some of the magnets, to what extent will manufacturing technologies that U.S. companies develop be given away to foreign countries?

Answer: Foreign countries (Italy, Germany, and Japan) have already demonstrated the ability to build magnets of a design that is similar or identical to that used in the SSC. Thus, if foreign countries should end up building some of the magnets, no substantial manufacturing technology is expected to be transferred.

Question #10: Foreign contributions for the detectors for the SSC are not included in the SSC cost estimate. Could you explain how much these contributions will be? What countries are providing them?

Answer: Strong foreign participation and interest in SSC detectors has been shown in the Expressions of Interest and Letters of Intent. There is work already underway in several areas, and we believe that there is a high probability of very significant contributions.

In the detector Letters of Intent submitted to the SSC Laboratory in November 1990, each of the major detector proposers identified contributions from many countries and institutions for equipment and manpower, comparable in value to the U.S. commitment to the construction of the detectors of about $500 million. These include institutions in the USSR, China, Czechoslovakia, Japan, England, France, Israel, Canada, Germany, Bulgaria, Hungary, Italy, Romania, Switzerland, and Korea. Although the Laboratory had determined that it is not possible to proceed with L* as proposed, a new collaboration is being formed and we are confident this will result in a second large detector.

Formal agreements on the final scope and full extent of these contributions are expected to be firmly established by mid-1992.

Question #11: The Department does not include foreign contributions toward the detectors because the Department believes that detectors meeting the SSC design specifications can be built without these contributions. Nonetheless the Department is pursuing these contributions and apparently expects to receive them. What capabilities will these additional contributions add to the detectors? Will these capabilities allow for experiments that would not otherwise be possible? Specifically, what will the SSC be able to do with the detectors built with foreign contributions that the SSC could not with detectors built without foreign contributions?

Answer: Foreign contributions toward the detectors are not included in the SSC Total Project Cost because sources of funding and the process of selecting, defining, and fabricating detectors are traditionally quite different than those for accelerators. Detectors for large high energy physics facilities are designed and built by large international collaborations composed of individual scientists, universities, and other "institutions". There is a long history of many successful collaborations that have built large detectors with substantial international participation and cost-sharing.

With the expected foreign contributions, the SSC experimental program would be carried out with two large, general-purpose detectors with complementary, as well as overlapping, capabilities. In addition, there would be several smaller, more specialized detectors. The two large, general-purpose detectors will provide a full spectrum of particle identification capabilities: precision energy, momentum, and position measurements; and full angular coverage for particle detection.

A viable and productive initial SSC experimental program could be supported without foreign contributions. It would most likely involve one large detector and several smaller experiments. Foreign contributions would allow a deeper and more diverse exploration of SSC physics opportunities as part of the initial program. Specifically, the SSC Laboratory and its Program Advisory Committee are persuaded that two large detectors are very desirable and are possible with the foreign support that seems likely on the basis of the Letters of Intent for major experiments submitted to the SSCL on November 30, 1990.

Question #12: Based on experience with other particle accelerators, what is the expected useful life of the SSC?

Answer: The SSC is expected to have a useful life of at least 25 years after commencement of operations. All the major systems and facilities, conventional construction, and support infrastructure facilities are being designed with this time period in mind. The lifetime projection for the SSC is consistent with the operating history of the three major DOE High Energy Physics (HEP) facilities. The Brookhaven Alternating Gradient Synchrotron (AGS) facility has been in operation over 30 years, the Fermilab main ring for nearly 20 years, and the Stanford Linear Accelerator Center (SLAC) linac for 24 years; all are still productive facilities. SLAC, Fermilab, and Brookhaven are three DOE-supported major accelerator centers that were all put in operation in the 1960's and 1970's.

Question #13: Some say that CERN's proposed "17 tev" proton-proton collider will do much of the same physics as the SSC. Is this correct? To what extent is this country planning to collaborate with the Europeans on their proposed accelerator? Should we be collaborating with the Europeans? What is the status of the CERN proposal? To what extent does CERN's efforts to get contributions for its project compete with our efforts to get money for the SSC?

Answer: The 1990 HEPAP Subpanel on SSC Physics chaired by Sidney Drell concluded that lowering the beam energy of the SSC to below a total of 30 TeV (15 TeV per beam) "would unacceptably increase the risk of missing important new physics." A machine with total energy of 17 TeV (8.5 TeV per beam), such as discussed at CERN, does not have the same physics discovery potential as discussed for the SSC, which has a total energy of 40 TeV. Research and development on the CERN project continues, especially on their more complicated magnets, but there has not been a formal decision to go ahead with construction.

Although there are no specific plans to participate in the construction of the Large Hadron Collider (LHC), there may be participation of U. S. scientists in the detector collaborations which do experiments at the LHC facility.

There is no direct competition for funds between CERN and the SSC. In fact, the SSC Laboratory and the Director-General of CERN just recently signed an agreement on cooperation between the two laboratories. Although the European community remains committed to support CERN, they have shown substantial interest in participating in the SSC detector collaborations.

Question #14: Setting priorities in research funding is very important. Is the SSC the highest priority for the Office of Energy Research at DOE? How does it compare to the human genome project and fusion as a priority for funding in the DOE research budget? Please prepare a list of priorities for basic science programs and projects carried out within the Office of Energy Research.

Answer: As a Presidential initiative, the SSC has highest priority for the DOE Office of Energy Research (OER). However, the Administration's and Department's position has been, and continues to be, that the SSC not come at the expense of other science (including the base high energy physics program). Not only does the President's FY 1992 budget request demonstrate this, but it also shows his high priority for R&D across the board. This has included a 16 percent increase for research sponsored by the NSF and a broad range of initiatives in OER to strengthen R&D in several areas, including the genome project and fusion as mentioned in the question. The fabric of today's R&D enterprise is tightly interwoven, and a weakness in one area will quickly have negative ramifications in others. In addition, past history has repeatedly demonstrated that the most valuable and far-reaching discoveries are often those least expected. Thus, it is important that all fields of science and technology be given adequate support and the tools needed to move forward. The SSC, the human genome project and the fusion program all are of high priority. Each reflects a different national objective, and each has important aspects such as the development of education, human resources, and institutional and regional scientific

capabilities. These projects are also very timely in relation to scientific need and opportunity.

While lists can be prepared for priorities within the Office of Energy Research, they would be limited in usefulness because major projects and programs within the Office of Energy Research are not competing to attain the same objectives.

Question #15: What is the status of the L* detector proposal by Dr. Ting?

Answer: The L* Letter of Intent, with Professor Sam Ting as spokesman, was submitted on November 10, 1990, and reviewed by the SSC Laboratory's Program Advisory Committee (PAC). Although L* has been identified as the second large detector collaboration, it has not been approved by the SSC Laboratory with support to proceed in the development of a full technical proposal/design report, pending further review and PAC recommendation. The SSC Laboratory has just determined that it is not possible to proceed with L* as proposed by the leaders of the collaboration. The Laboratory will begin discussions immediately with members of the L* collaboration and others to discuss the formation of a new international collaboration which we are confident will result in a second large, complementary detector.

Question #16: Is the total cost of the two large detectors still $910 million?

Answer: The $910 million allowance in the baseline is the estimate of the total cost to the Federal government for two large detectors, two small experiments, detector research and development to support all detectors, and experimental computing. This allowance of U.S. funds, together with expected foreign contributions, will provide the detectors for the initial SSC experiment. The total of foreign contributions to the large detectors is expected to be on the order of $250 million per detector, depending on the final scope of the detectors and the formal commitments agreed to with the collaborations.

Question #17: How much of the operating costs that will be incurred before the SSC is finished will come out of the High Energy Physics Program budget and not the SSC budget? Do these costs not raise the total amount of cost of the SSC above the current $8.3 billion estimate?

Answer: Operating cost for activities beyond those required to commission the SSC and make it operational will be funded from a separate SSC line in the high energy physics (HEP) budget. These costs are currently under review by the Office of SSC and the Office of High Energy and Nuclear Physics. The estimate for these costs, included in the baseline report, is a total of $460 million over the last 7 years of the construction project. The actual cost of these operations will depend on the level of effort supported by the high energy physics community for experiments and operations of the new SSC Laboratory. These operating costs for the newly established SSC Laboratory are not included in the Total Project Cost (TPC) because they are largely user driven, are variable, and are not activities that are directly required for construction.